MANUFACTURING TEXTILE FUTURES: ADAPTATION, COMPETITIVENESS AND THE EVOLUTION OF UK TECHNICAL TEXTILE FIRMS

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ABSTRACT

Economic geography used to be dominated by studies of manufacturing, but over the past thirty years, the study of manufacturing has been neglected. In recent years, especially since the financial crisis that commenced in 2008, there has been a renewed interest in the academic debates on manufacturing firms located in developed market economies. Manufacturing continues to be fabric of the UK economy, as firms have transformed and restructured themselves in response to new forms of competition, alterations in consumer demand and new technological developments. This thesis applies evolutionary approaches to the UK technical textile (TT) sector to investigate the adaptation and evolution of UK TT firms. TT products are advanced materials that are embedded in other products as intermediate components. TT is a high value-added and advanced segment of the textiles industry and provides an example of industrial evolution from pre- to post-industrial worlds in developed market economies.

The evolutionary economic geography (EEG) framework provides a theory on how the industrial evolution of the UK textiles industry to TT is shaped by the micro-behaviour of firms. This thesis blends EEG approaches with the resource-based view (RBV) of the firm into a new conceptual framework, to develop a novel firm-centred approach to understanding firm-based competitiveness and evolving economic geographies of manufacturing. This theoretical blend highlights how a focus on routines (EEG) must be combined with an understanding of resources and capabilities (RBV) to theorise firm behaviour. A detailed comparative firm-level analysis of 40 TT firms located across the UK identifies the adaptation processes and drivers behind firms diversifying into the manufacture of TT.

This thesis makes a theoretical contribution to understanding how the adaptation processes of firm's routines are an evolutionary process to firm-based competitiveness, in response to changes in their external economic environment. Routines are developed by micro-processes and practices, which build upon and engage with firm-specific resources. UK TT firms have implemented competitiveness strategies related to cost management and non-price-based strategies, which are related to exploiting advantages linked to location and connectivity, providing firms with geographical competitive advantages over competitors located in low-cost locations. This study emphasises how there are co-evolution strategies between the dynamic capabilities of firm's employees and the adaptation of their routines. UK TT firms are experiencing skill shortages, which are becoming a critical barrier to the adaptability of firm's routines and the sustainable evolution of the UK TT industry, the ability to sustain an evolving and positive trajectory.

Key Words: Manufacturing, Adaptation, Routines, Competitiveness, Evolution

For Joe

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GLOSSARY OF TEXTILE TERMS

COMPOSITES – A product formed by intimately combining two or more discrete physical phases, usually a solid matrix and a fibrous material.

MEDICAL TEXTILE – A general term which describes a textile structure which has been designed and produced for use in any of a variety of medical applications, including implantable applications.

TECHNICAL TEXTILE – Textile materials and products manufactured primarily for their technical performance and functional properties rather than their aesthetic or decorative characteristics.

TEXTILE – A textile was originally a woven fabric, but the terms textile and the plural textiles are also applied to fibres, filaments and yarns, natural and manufactured, and most products for which these are a principal raw material.

FIBRE AND YARN PREPARATION

BLENDING – A process or processes concerned primarily with the mixing of various lots of fibres to produce a homogeneous mass. Blending is normally undertaken to mix fibres, which may or may not be of similar physical or chemical properties, market values, or colours. Blending is also used to ensure consistency of end product.

ELECTROSPINNING – Manufacture of Nanofibres from polymer solutions usually by capillary method, wherein a pendant droplet of the polymer solution at the capillary tip is subjected to the electric field created by the potential difference between the capillary and a grounded collector. This creates an instability that deforms the hemispherical droplet into a cone shape, often referred to as a Taylor cone.

FIBRE – Textile raw material generally characterised by flexibility, fineness and high ratio of length to thickness.

FILAMENT – A fibre of indefinite length.

GLASS FIBRE – Fibre, in textile form, obtained by drawing molten glass. In practice, extrusion or other spinning processes also produce glass filament or fibre.

MELTBLOWING – A process in which a polymer is melt-extruded through a die into a high velocity stream of hot air, which draws it into fine and relatively short fibres. After quenching by a cold air stream the fibres are collected as a sheet on a moving screen.

METAL FIBRES – A manufactured fibre composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal.

MINERAL FIBRES – An inorganic fibre, natural or manufactured.

NANOFIBRES – The manufacture of fibres of 100 nanometres less in diameter by electrospinning of fibres from polymer solutions or from molten polymers.

NATURAL FIBRES – A fibre occurring in nature. Fibres are found in all three sectors of the natural world, for example animal (silk and wool), vegetable (cotton and jute) and mineral (asbestos).

REGENERATED FIBRES – A fibre formed from a solution of a natural polymer or of a chemical derivative of a natural polymer and having the same chemical constitution as the natural polymer from which the solution or derivative was made.

SPINNING – The present participle of the verb 'to spin' used verbally, adjectively, or as a noun, meaning the process, or the processes, used in the production of yarns or filaments.

SYNTHETIC FIBRES – A fibre manufactured from a polymer synthesised from chemical elements or compounds, in contrast to fibres made from naturally occurring fibre-forming polymers.

TWIST – The condition of a yarn or similar structure when the component elements have a helical disposition such as results, for instance, from relative rotation of the yarn ends.

WARP THREAD – Yarn intended for threads to be lengthways in a fabric.

WEBS – single or multiple sheets of fibre.

WEFT THREAD – Yarn intended for threads to be widthways in a fabric.

YARNS – A product of substantial length and relatively small cross-section consisting of fibres and/or filament(s) with or without twist.

MANUFACTURING PROCESSES

ADHESIVE-BONDED (Nonwoven) – Textile material composed of a web of fibres, bonded by the application of adhesive material in liquid form. Methods of application include saturation bonding, spray bonding, print bonding and foam bonding.

BOBBINET (Weaving) – A cotton face net produced on a bobbinet machine. Bobbinet is a woven fabric made up of warp and weft yarns in which the weft yarns are looped diagonally around the vertical warp yarns to form hexagonal mesh, which is regular and clearly defined.

BRAIDING – The process of interlacing three or more threads in such a way that they cross one another in diagonal formation. Flat, tubular or solid constructions may be formed in this way.

BRUSHING – A finishing process in which the fabric is passed over one or more revolving brushes in order to raise the surface fibres. This may be then followed by cutting, cropping or shearing (cutting of loose fibres or yarns from the surface of a fabric).

CALENDERING – The process of passing fabric through a calender in which a highly polished, usually heated, steel bowl rotates at a higher surface speed than the softer (For example, cotton or paper-filled) bowl against which it works, thus producing a glaze (a smooth, glossy, plane surface) on the face of the fabric that is in contact with the steel bowl.

COATED FABRIC – A textile fabric on which there has been formed in situ, on one or both surfaces, a layer, or layers, of adherent coating material.

DYEING – The application and fixing of a dye to a substrate, normally with the intention of obtaining an even distribution throughout the substrate.

FELT – A textile fabric characterised by the entangled condition of many or all of its component fibres.

KNITTING – The process of forming a fabric by the intermeshing of loops of yarn.

LOOM – A machine used for producing fabric by weaving.

NARROW FABRIC – Any fabric made by interlacing fibres or yarns, which (in the UK) does not exceed 45 cm in width. A characteristic of a narrow fabric is that its edges are an essential feature.

NEEDLEPUNCHING (Nonwoven) – The use of barbed needles mounted in a needleloom to entangle a fibre web by mechanical reorientation of some of the fibres within its structure.

NET – An open-mesh fabric, in which some form of twist, interlocking, or knitting of the yarn ensures a firm structure. It may be produced by gauze weaving, knitting, or knitting, or on a lace machine.

NONWOVEN – Fabrics normally made from continuous filaments or from staple fibre web strengthened by bonding using various techniques: these include adhesive bonding, mechanical interlocking by needling or fluid jet entanglement, thermal bonding or stitch bonding.

ROPE – An article of cordage, more than approximately 4mm in diameter, obtained when: (i) three or more strands are laid or plaited together; or (ii) a core is covered by a braided or plastic film sheath.

SILK – The protein filaments forming the cocoons produced by silkworms. The natural filaments are covered by sericin (silk gum), which is usually removed in processing.

THREE-DIMENSIONAL FABRIC – A three-dimensional structure used as reinforcement in composite materials, consisting of three mutually orthogonal matrices of closely spaced parallel yarns.

WARP KNITTING – A method of making a fabric by normal knitting means in which the loops made from each warp thread are formed substantially along the length of the fabric.

It is characterised by the fact that each warp thread is fed more or less in line with the direction in which the fabric is produced.

WEAVING – The action of producing fabric by interlacing of warp and weft threads.

WEBBING (Weaving) – A woven narrow fabric, the prime function of which is load bearing, generally with multiple piles.

WEFT KNITTING – A method of making a fabric by normal knitting means in which the loops made by each weft thread are formed substantially across the width of the fabric. It is characterised by the fact that each weft thread is fed more or less at right angles to the direction in which the fabric is produced.

FINISHING PROCESSES

BIOPOLISHING – Treatment of cellulosic fibre substrates, e.g., fabric or garments, with a cellulose enzyme under acid or neutral pH conditions to remove surface hairiness, and impart enhanced fabric appearance. Biopolishing decreases fabric weight and is an example of a subtractive finish.

BREATHABLE FABRIC – A term frequently used to describe fabrics used in outdoor clothing offering high levels of resistance to liquid water (usually rain) penetration and wind resistance but a relatively low level of resistance to water-vapour transmission, especially when dry. Includes fabrics with breathable coatings and laminates with a water resistant but breathable membrane.

FINISHING – Description of processes, physical or chemical, applied to a substrate to produce a desired effect.

FLAME RETARDANT TREATMENT – Chemical process or treatment whereby improved flame resistance is imparted to a material. One or more flame-retardants may be applied during textile finishing or coating, or in the case of manufactured fibres, introduced into the fibre during fibre production.

LAMINATED FABRIC – A material composed of two or more layers, at least one of which is a textile fabric, bonded closely together by means of an added adhesive, or by the adhesive properties of one or more of the component layers.

PLASMA TREATMENT – An electrical discharge treatment carried out under vacuum, and used to modify the surfaces of fibres.

PROOF (Resistant) – Fully resistant to a specified agency, either by reason of physical structure or inherent chemical non-reactivity, or arising from a treatment designed to impart the desired characteristics. Proofing treatments are defined by specified limits ascertained by test, and the use of the term is related to the limiting conditions.

SETTING – The process of conferring stability of form upon fibres, yarns, fabrics, or garments, usually by means of a single or multiple cycles of heating and cooling in dry or moist conditions

SUBSTRATE – A material, e.g., fibre, yarn, fabric, to which dyes, pigments and other substances may be applied and into which they may be absorbed.

WICKING – The penetration of liquids, under the influence of capillary forces, along or through a textile material or the textile element of a coated or along interstices formed by the textile element and the coating polymer of the coated fabric.

Source: TT&D (2015)

LIST OF ABBREVIATIONS

3D	Three-Dimensional
BIS	Department for Business, Innovation and Skills
CAD	Computer Assisted Design
DRA	David Rigby Associates
DTI	Department of Trade and Industry
EEF	Engineering Employment Federation
EEG	Evolutionary Economic Geography
ESRC	Economic and Social Research Council
EU	European Union
FAME	Financial Accounts Made Easy
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GVA	Gross Value Added
IAB	Industrial Advisory Board
IoD	Institute of Directors
IVC	Innovation Value Chain
KTP	Knowledge Transfer Partnership
M&A	Merger and Acquisition
MFA	Multi-Fibre Agreement

NDA	Non-Disclosure Agreement
NIDL	New International Division of Labour
OEM	Original Equipment Manufacturer
ONS	Office for National Statistics
R&D	Research and Development
RBV	Resource-Based View
RDA	Regional Development Agency
SCA	Sustainable Competitive Advantage
SIC	Standard Industrial Classification
SME	Small and Medium Sized Enterprise
STEM	Science, Technology, Engineering and Mathematics
TCSG	Textile & Clothing Strategy Group
TI	The Textile Institute
TNC	Transnational Corporation
TSB	Technology Strategy Board
TT	Technical Textiles
TT&D	Textile Terms & Definitions
UK	United Kingdom
UKTI	UK Trade and Investment
USA	United States of America

1 ADAPTATION AND EVOLUTION OF UK TECHNICAL TEXTILE FIRMS

1.1 Introduction

What can be stronger than steel, lighter than air, safer than chain mail and is able to stop bullets at close range and hoist a satellite into orbit? (McQuaid, 2005; Quinn, 2010). The answer to the above question is something that is part of our everyday physical environment – lying under roadbeds, reinforcing concrete columns, within car parts, ski helmets and implanted into humans – technical textiles (McQuaid, 2005). Textiles are any product made from a fabric and produced for clothing, curtains, bedding and soft toys (Eason, 2009), whereas, technical textiles are 'textile materials and products manufactured primarily for their technical and performance properties rather than their aesthetic or decorative characteristics' (TT&D, 2015). Throughout this thesis, technical textile is abbreviated to TT to differentiate between 'traditional' textiles and technical textiles.

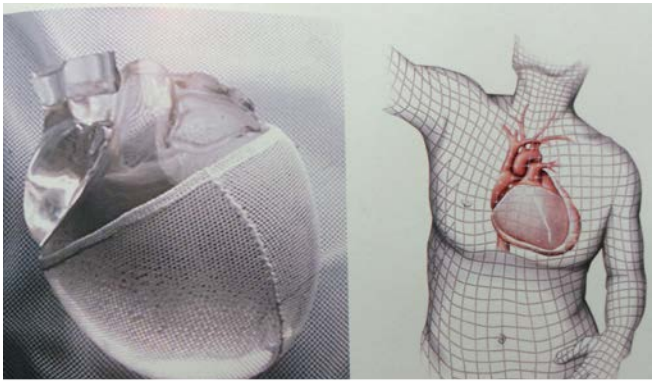
Traditional textiles are a mature segment of the UK textile industry, which has suffered from 'a strong increase in competition from emerging economies in East Asia' (Hassink, 2010: 461) and a consequential decline in the size of the sector (Dicken, 2011). The UK textile industry peaked in 1973, employing 851,000 workers (ONS, 2014). By 2013, textiles accounted for 3 per cent of total manufacturing in the UK and employed 85,000 workers

(Lee, 2013; ONS, 2014). Between 1973 and 2013, output fell by 68 per cent and the number of employees by 90 per cent (ONS, 2014). TT is an emerging, innovative and advanced segment of the UK textiles industry. It is a smaller segment of the textiles sector in terms of volume but higher in terms of value-added and is growing four times faster than traditional textiles (TSB, 2008). Furthermore, TT has 'proved to be particularly resilient in the face of overseas competition and adept at finding profitable niche markets and applications for their products' (Alliance, 2015: 19).

TT has unusual characteristics compared to traditional textiles. For TT firms, there is a focus on the innovation in the functions performed by textiles. TT products are advanced materials that are embedded in other products as intermediate components. Manufacturing processes of TT involves more research and development (R&D) activities as products are co-produced with customers (Loch *et al.*, 2007). Firms design, develop and engineer a textile solution that meets the requirements of the customer, with numerous products becoming accredited and certified to industry regulations of a particular market (DRA, 2001). The UK TT industry plays a strategic role in providing solutions for many other industries including automotive and aerospace applications, protective clothing (radiation and heat protection), architecture (inflatable buildings, building structure reinforcement), agriculture (ground drainage, soil slope reinforcement), sportswear (sun protection, wicking fabrics), protective textiles (bulletproof clothing, stab protection) and medical textiles (Byrne, 2000; O'Mahony, 2007; Quinn, 2010). Medical TT can be embedded within the human body, providing a technical function, in the form of textile stents to repair

damaged blood vessels which promote in-tissue growth, and warp-knit mesh bags used to treat an enlargement of the heart (Figure 1.1) (Brown, 2005; Quinn, 2010). These new technological developments in TT has led to a renewal and diversification of the UK textile industry (Hassink, 2010).

Figure 1.1: An Example of a Medical TT: Cardiac Support Device



Source: Brown 2005: 49.

Industrial evolution is the change, restructuring and technological progress of a particular economic sector (Boschma and Martin, 2010; Nelson and Winter, 1982; Rigby and Essletzbichler, 1997). The evolution of the UK textile industry to TT is about the adaptation of firms, the reallocation of their resources and capabilities to new organizational forms (Chakravarthy, 1982), in response to changes in their competitive environments and dynamics (Martin, 2010). To remain competitive as a manufacturer of textile products in the UK, some 'textile companies have been successful in re-orientating themselves towards TT' (Hassink, 2010: 461). TT can be produced in high-cost locations due to the value-added through its innovative and sophisticated technology, and knowledge-intensive processes

(Hassink, 2007; Livesey, 2006). This thesis identifies the adaptation processes and drivers behind UK firms diversifying into the manufacture of TT (Alliance, 2015; Byrne, 2000; Hassink, 2010).

The competitiveness and evolving economic geographies of these UK manufacturing firms is examined through a blend of two related theoretical approaches: Evolutionary Economic Geography (EEG) (Aldrich and Ruef, 2006; Boschma and Martin, 2007, 2010; Nelson and Winter, 1982) and the Resource-Based View (RBV) of the firm (Barney, 1991; Hoopes *et al.*, 2003; Penrose, 1959; Wernerfelt, 1984). The RBV of the firm informs an understanding on firm-based competitiveness (Barney, 1991; Bryson and Taylor, 2010; Hoopes *et al.*, 2003), and the EEG perspective contributes an understanding on the industrial evolution of the UK textile industry to TT, explaining how it is shaped by the micro-behaviour of firms (Boschma and Martin, 2007; Essletzbichler and Rigby, 2007; Nelson and Winter, 1982; Schamp, 2005).

This chapter introduces TT and provides a background to the thesis. It is divided into four main sections. The first section investigates the evolution of the UK textile industry into the new, more value-added sub-segment of textiles, TT (Hassink, 2007). The second section examines the industrial recognition of the TT sector and develops a definition of TT. The third section outlines the research questions and approach of the thesis. The fourth and final section provides a summary and overview of the thesis structure.

1.2 Evolution of the UK Technical Textile Industry

Since the 1960s, the processes of globalisation, 'the stretching and deepening of social relations and institutions across space and time' (Held, 1995: 20) assisted by technological developments in transport, communications and liberalisation of policies (Castells, 2003; Peet *et al.*, 2011), has caused an increasing fragmentation of production. The mobility of capital and the 'new international division of labour' (NIDL) has enabled firms to coordinate their production activities over different geographical scales (Dicken, 2011; Sunley, 2011), and resulted in some manufacturing activities to move to developing market economies (Gereffi, 2005). Developing market economies have a comparative advantage in producing labour intensive goods cheaper and in higher volumes, due to lower wage rates, longer working hours and reduced environmental regulations (Daniels, 2005). In developed market economies, this has led to a relative deindustrialisation, 'a sustained decline in industrial activity and capacity' (Lee, 2000: 158), of mature manufacturing sectors (textiles, shipbuilding and tool making), which are labour intensive, low value-added and high volume (Dicken, 2011).

The textile industry was the first to adopt a global dimension to developing market economies due to its low barriers of entry; textile production is relatively low-skilled, and principally suited to the early stages of industrialisation (Rostow, 1990). The textile industry is one of the most labour-intensive industries, with labour costs in clothing production equating to around 60 per cent of total costs (Dicken, 1986). Given the cost structure of this industry, developing nations became dominant in producing textiles (Chapman, 1987). In

the early twentieth century Britain became a major exporter of textile machinery to firms located in India, China and Japan, assisting in the development of their own textile industries (Court, 1965). This resulted in an unprecedented growth in price-based competition experienced by developed market economies from firms based in low-cost textile locations (Bryson and Taylor, 2010). By the 1960s, imports of cotton into the UK had outmatched exports for the first time and mills were closing at the rate of almost one a week (Fowler, 2003). Between 1974 and 2005, developed market economies enforced the Multi-Fibre Agreement (MFA), imposing quotas on low-cost imports, in an attempt to protect their own textile industries (Hudson, 2002). After its removal, the influx of price-based competition further reduced UK's manufacturing capacity in textiles and Asia's dominance grew to generating over 50 per cent of the world total of textile exports (Dicken, 2011).

Today, the UK textile industry has three outputs: household goods, clothing and fashion, and textiles. A majority of the textile industry has moved offshore to developing market economies, especially in the case of household goods and clothing (Dicken, 2007; Gereffi, 1994; Scott, 2006). However, some firms of traditional textiles have remained resilient through adaptive and competitive strategies. The industry includes producers of traditional fabrics, for example Harris Tweed, which is hand-woven by the islanders at their homes in the Outer Hebrides, Scotland, competing on skills, heritage and brand (Platman, 2011). It also includes a group of seventy-six firms engaged in the advanced manufacturing segment of the textiles industry, technical textiles.

Emergence of a Technical Textile Industry

Textiles have always been used in alternative applications to clothing and furnishing. For example, there is evidence of woven fabrics being used in Roman times to stabilise marshy ground for road building (Byrne, 2000). Nevertheless, it was the innovative interface between the textile and chemical industries since the late 19th century that was the catalyst for the emergence and development of TT (Braddock-Clarke, 2007a; Byrne, 2000). The blend of these two technologies created new chemical finishes and artificial fibres, especially synthetics, acrylics and nylon (Braddock-Clarke, 2007a; Murmann, 2013). Nylon was the first truly synthetic fibre developed by Wallace Carothers from research on polymers (very large molecules with repeating chemical structures) in DuPont's experimental station (DuPont, 2013). Nylon was commercialised in 1939 for ladies' hosiery. However, its properties of high strength, elasticity and resistance to moisture meant it was quickly channelled into alternative applications, for example, military parachutes (Byrne, 2000). In the 1940s, polyester was invented by British chemists J.R. Whinfield and J.T Dickson, employees of the chemical company Imperial Chemical Industries (Braddock-Clarke, 2007a). Similar to the case of Nylon, polyester quickly became utilised in textiles for its properties of smoothness, strength, natural elasticity and resilience (Braddock-Clarke, 2007a; Byrne, 2000).

The triad of developed market economies, the USA, Japan and Europe, led the development and growth of TT. By 2000, TT accounted for over 50 per cent of all textile manufacturing activity and output in these economies (Byrne, 2000). The USA developed its

TT industry through key developments in glass and technical fibres and Japan became regarded as pioneers in developing fabric and high performance fibres, especially for automotive applications (Braddock-Clarke, 2007a; Byrne, 2000). Western Europe led the progress in composites, 'where two or more materials, differing in form or composition, are combined to make a new material with enhanced performance characteristics', utilised in construction, automotive and aerospace industries (O'Mahony, 2007: 72). Moreover, western Europe led with the advancements in textile machinery, due to leading equipment manufacturers being based in Germany, Belgium, Switzerland, Austria and Italy (Wilson, 2014). Germany in particular, as the world leader in the synthetic dye industry in the early twentieth century (Murmann, 2013), has been a key player in the development and emergence of the TT industry (O'Mahony, 2007). Germany became the international 'hub' of the TT industry with Techtextil, a sector-based institution and the largest trade exhibition for TT organised every two years by Messe Frankfurt (Byrne, 2000).

During the 2000s, western Europe continued to occupy the top international TT market position (Cherif and Adolphe, 2010) and directed a great deal of the technological developments in TT. The Seventh Framework Research Programme (FP7) provided funding for TT innovation projects between 2007 and 2013 (CORDIS, 2015), and the European Research Area (ERA) played an important role in creating a networked space for TT businesses across Europe for collaborative and innovative research (ERA, 2015; Euratex, 2013). For example, the Stay Cool research initiative is a partnership of seven manufacturing firms and research institutions, to develop and prototype a novel system for

cooling the body that is lightweight, has low energy consumption and could be worn by fire-fighters for prolonged periods of time (Ronayne, 2012; StayCool, 2015). Western Europe also contains the world's largest advanced textile materials cluster, Textile 2020, which represents nine hundred organisations and is supported by the European's Commission (EC) Competitiveness and Innovation Framework Programme (CIP) (EC, 2015; Textile2020, 2015). TT continues to be centralised in Germany with Techtextil as the principal platform for approximately 1,300 exhibitors from forty-eight countries, to showcase their latest TT innovations to nearly 28,000 visitors from ninety-seven different nations (Techtextil, 2015b).

The UK is regarded as a world leader in the field of TT (UKTI, 2011b). The UK TT industry services the needs of a number of end user markets and industry sectors, including: automotive; composite materials; industrial filtration, performance work-wear and technical/smart garments (Alliance, 2015). The industry is characterised by small and medium sized enterprises (SMEs), which 'produce only TT or a combination of TT and 'traditional textiles' (DTI, 2007: 4). These firms are located in 'areas that form part of the UK's former "textiles industrial heartland", namely Greater Manchester, Lancashire and Yorkshire, and in the regions around Leicester and Nottingham' (Alliance, 2015: 19). In 2007, David Rigby Associates (DRA) estimated that 24,000 people were directly employed in the UK TT industry (NWtexnet, 2008), but 'this figure is likely to be rather larger if indirect employment and downstream manufacturing is included' (DRA, 2001: 32). The sector has a

highly international focus, with 70 per cent of TT products being exported (NWtexnet, 2008).

Despite these statistics, an initial challenge to this thesis has been to identify the UK TT sector. Given the complexity of the sector (Section 1.3) and because it is 'changing too rapidly to define and document' (Byrne, 2000), there is inconsistent statistical reporting on the scope of TT in the UK. It is estimated that the TT sector contributes between £1.5 billion and £2 billion to the UK's economy (Alliance, 2015), although Skillset, the sector skills council that represents the industry, suggest that in reality this figure may be closer to £4 billion (DTI, 2007). NWtexnet (2012), a TT trade body, estimates there are 450 companies involved in the production of TT in the UK, whereas the Financial Accounts Made Easy (FAME) database identifies 172 companies classified in the Standard Industrial Classification (SIC) (2007) of TT (SIC 1396).[1] Due to this variable reporting, this thesis has had to construct a working definition (Section 1.3) based on the identification of the characteristics of the UK TT industry. This process is explained further in Chapter 3.

1.3 Definition Development: Understanding Technical Textiles

The development of TT has been a 'quiet' revolution, as it was not until the 1980s that its existence and potential was widely recognised (McQuaid, 2005). The term TT was coined in 1985 at the first Techtextil exhibition; Techtextil had a significant influence in defining TT

[1] The FAME database is of UK VAT registered firms and provides financial information and business intelligence on UK and Irish registered companies (BVD, 2015).

globally (Byrne, 2000). TT superseded the earlier term *industrial textiles*, used to describe all textile products other than those intended for apparel, household and furnishing end uses. Industrial textiles became unsuitable, with wider technological developments in textiles for medical, sports and transportation applications (Byrne, 2000). The term TT incorporates the growing diversity of textiles with technical properties (Macbeth and Miln, 2012). Techtextil introduced and defined twelve product application categories of TT, of which industrial textiles are now one subgroup (Table 1.1).

Table 1.1: Technical Textile Application Categories

1	Agrotech	Agriculture, horticulture, forestry and landscape gardening
2	Buildtech	Architecture and building: membrane constructions, lightweight and solid structures, earthworks and hydraulic engineering
3	Clothtech	Technical components of shoes and clothing manufacture e.g. linings
4	Geotech	Civil engineering materials, road construction, dam and waste site construction
5	Hometech	Technical components of furniture, upholstery, floor coverings and carpets
6	Indutech	Textiles for industrial applications: mechanical engineering, chemical and electrical industries. For example, filtration, conveying, cleaning
7	Medtech	Hygiene and medical products
8	Mobiltech	Ship and aircraft construction, automobiles, railway and space travel
9	Oekotech	Environmental protection, waste disposal and recycling
10	Packtech	Packaging, covering and transportation materials
11	Protech	Personal & property protection
12	Sporttech	Sport & leisure products

Source: (Techtextil, 2015b).

TT is a complex and heterogeneous sector with a diverse number of actors and industries including paper, chemicals, metals and minerals (McQuaid, 2005; O'Mahony, 2007; Quinn, 2010). The widely accepted definition of TT provided in Section 1.1 is not inclusive of all these industries, and is becoming increasingly ambiguous with significant boundary issues as 'an increasing number of products are combining both performance and decorative properties and functions in equal measures' (Byrne, 2000: 2). A sports shoe for example, consists of 'technical' shoe components (hidden & functional) and 'non-technical' shoe uppers (visible and largely aesthetic) (DRA, 2002). It has remained difficult for scholars and industry to construct a precise definition of TT. The current universal definition of TT conceptualises the industry through historical dimensions of the main manufacturing sectors, rather than a market-based view of the products involved (Byrne, 2000). This has become a common limitation for current frameworks attempting to classify modern manufacturing industries (Bryson *et al.*, 2008).

It is the higher value-added fabric manufacturers who are maintaining textile-manufacturing systems in the UK (Alliance, 2015). A focus on the textile fabric produced would therefore identify which firms are producing highly innovative products, creating value. A definition needs to foreground TT producers that have engineered or scientifically advanced the fabric from different combinations of technical attributes to produce a TT (Table 1.2). Technical attributes of a TT consist of first, the textile fibre, second, the different manufacturing processes to produce the TT, and third, the finishing processes of the TT.

Table 1.2: Technical Attributes of Technical Textiles

TT Attributes	Possible Options and Combinations of the Three Different TT Attributes				
Textile Fibre	**Metals** *Steel; Copper; Aluminium.*	**Minerals** *Carbon; Glass; Ceramics.*	**Synthetic** *Polyester; Nylon; Acrylic; Elastomeric.*	**Regenerated** *Aramids; Rayon; Viscose; Acetate; Modal; Tencel.*	**Natural** *Cotton; Wool; Silk; Jute; Hemp.*
Manufacturing Processes	**Weaving** *Narrow; Broad; Bobbinet.*	**Knitting** *Warp;* *Weft.*	**Nonwoven** *Wetlaying; Thermal; Chemical; Needlepunching; Stitchbonding; Spunlacing.*		
Finishing Processes	**Physical** *Brushing; Calendering; Laminating.*	**Biological** *Bio-stoning; Bio-Polishing.*	**Chemical** *Water proofing; Flame proofing.*	**Coating** *Anti-Bacterial; PVC.*	

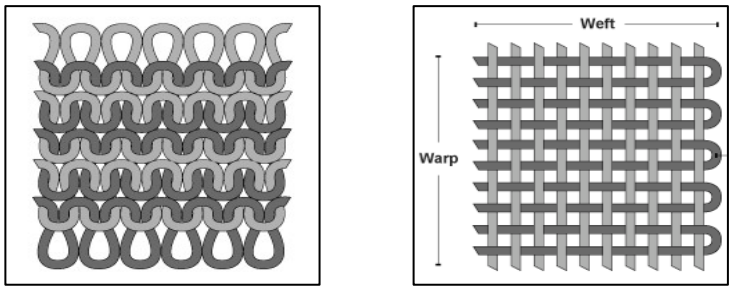
Source: DRA (2001) and Eason (2009). See Glossary for Definitions of Textile Terms.

Firms develop a TT by building in the use of one or a blend of textile fibres (metal, mineral, synthetic, regenerated or natural) to deliver a particular function. For example, regenerated or high-performance fibres are those that 'have exceptional strength, strength-to-weight ratio, chemical or flame resistance, or range of operating temperatures' (Brown, 2005: 36). The manufacturing process of the TT fabric includes the different traditional techniques of weaving and knitting processes, as well as the relatively newer methods of nonwoven bonding. Nonwoven textile manufacturing involves the 'cross-hatching of fibres going in all different directions' that are then 'bonded together by heat, pressure or needle punching' (Braddock-Clarke, 2007a: 22). Woven fabric is constructed from yarn that is interlocked in horizontal (weft) and vertical (warp) directions, whereas

knitted fabric is constructed from yarn that is interlocked in loops (Figure 1.2). The development of high-performance fibres has resulted in engineers re-examining the structural capabilities of these techniques (Brown, 2005). Different fabric structures can now enable a fabric to be breathable or three-dimensional (3D). Finishing processes provide specific properties that can determine what type of fabrics are produced, for example anti-bacterial, stain resistant, waterproof and/or windproof. An example of combining these technical attributes could include the composition of carbon fibre (*textile fibre*) plus 3D weaving (*manufacturing process*) to produce a base reinforcement material. A resin coating is then applied, to produce a pre-impregnated material (pre-preg), fillers to improve dimensional stability and additives for additional functionality such as flame retardency (*finishing processes*) (O'Mahony, 2007). The pre-preg is then moulded into a composite reinforcement TT fabric. TT can therefore be defined as a high value-added segment of the textile industry consisting of a group of firms producing textiles with the addition of multiple and varied technical attributes:

Textile Fibre(s) + *Manufacturing Process* + *Finishing Process(es)* = Technical Textile.

Figure 1.2: Technical Textile Production Techniques



Knitting **Weaving**

Source: BBC (2015)

1.4 Research Aims and Objectives

Manufacturing continues to be the fabric of the UK economy and plays a fundamental role in the nation's prosperity (Bryson *et al.*, 2008; Christopherson, 2011; Cohen and Zysman, 1987; Hudson, 2010; Kalafsky, 2007; Livesey, 2006). In the UK, manufacturing accounts for over 10 per cent of the gross value added (GVA), 8 per cent of employment, 53 per cent of exports, 72 per cent of business R&D (Foresight, 2013; Rhodes, 2014) and 42 per cent of industry innovation (Haskel *et al.*, 2011). Significantly, the British manufacturing sector has been resilient to external shocks such as the 2008 economic downturn (Pike *et al.*, 2012), as it has experienced a stable upturn in production and export orders into 2014, contributing to the rebalancing of the economy (Foresight, 2013; Markit, 2014).

Economic geography used to be dominated by studies of manufacturing activities (Cohen and Zysman, 1987; Miller, 1962), but over the past thirty years geographers began to turn their attention to understanding the changing role of business and professional services (Beaverstock, 2004; Beyers, 1993, 2002; Bryson and Daniels, 2007; Bryson *et al.*, 2004; Daniels, 1985; Lundquist *et al.*, 2008; Marshall *et al.*, 1987), financial services (Boyer, 2000; Clark, 2002; Corbridge *et al.*, 1994; Dore, 2008; Leyshon and Thrift, 1997; McDowell, 1997) and retailing (Crewe and Beaverstock, 1998; Goss, 1993; Wrigley *et al.*, 2005; Wrigley and Lowe, 1996, 2002). The reasons for this change in research focus is discussed further in Chapter 2. UK manufacturing firms have evolved to meet the competitive demands of the global economy in the 21st century, but this remains to be woven into the social science and political debates (Livesey, 2006). Bryson *et al.* (2008: 184) state, 'the alterations have

been so radical that it is possible to argue that economic geographers no longer understand manufacturing'. Consequently, there are key research gaps on understanding the adaptation of low value manufacturing sectors (construction and building materials, paper and packaging, food and drink, textiles, metals and locks) in high-cost locations (Bryson and Taylor, 2010; Mulhall, 2015; PricewaterhouseCoopers, 2009). Few empirical studies have examined how firms have adapted to engage in high value and advanced manufacturing activities, and developed new forms of competitiveness for a sustainable industrial manufacturing base (Bryson *et al.*, 2015a; Bryson *et al.*, 2008; Christopherson, 2011; Hudson, 2010; Livesey, 2006).

Furthermore, the adaptation of textile manufacturing firms to TT has been overlooked in the social sciences. Research into the economic geography of the textile industry in developed market economies has been replaced by a focus on research into the manufacturing of clothing in low wage economies (Dicken, 2007; Pickles and Smith, 2011; Reimer, 2009; Scott, 2006; Tokatli *et al.*, 2008; Wrigley *et al.*, 2005). These accounts have predominately employed Global Value Chain (GVC) (Gereffi, 1999; Gereffi *et al.*, 2005) or Global Production Network (GPN) frameworks in their analyses (Coe *et al.*, 2004; Coe and Yeung, 2001; Henderson *et al.*, 2002), which conceptualise the complexity of linkages and circulation of capital, knowledge and people in the production of goods (Coe *et al.*, 2008).

The GPN approach is part of the relational turn in economic geography, the study of 'the ways in which socio-spatial relations of actors are intertwined with broader structures and

processes of economic change at various geographical scales' (Yeung, 2005: 37). The GPN approach aims to conceptualise the global organisation of industries (Gereffi, 2005), and so have a macro-level approach to understanding economic activity at global, national and regional spatial scales (Bryson and Rusten, 2011). The unit of analysis, in GPN approaches, are inter-firm networks across the whole production process of sectoral industries (Coe 2011). There is a focus on the points within the network of where value is created, the complex power relations and the broader institutional context (trade policy, regulations and standards) of firm's linkages in a global economy (Coe *et al.*, 2008; Coe and Yeung, 2001; Gereffi, 2005). The firm is treated as a 'black box', as it is assumed a firm's traditional organisational boundaries become blurred when integrated in network relations (Henderson *et al.*, 2002).

Firms are drivers of economic change, as their behaviour and decision-making affects the economic system (Boschma and Martin, 2007; Hoopes *et al.*, 2003) and equally the economic system (external forces) affects, as well as influences the adaptation of firm's routines (Coase, 1937; Taylor, 2006). Routines are firm-specific resources and capabilities blended into settled and repeated patterns of behaviours (Aldrich and Ruef, 2006; Nelson and Winter, 1982). The GPN framework neglects to develop an understanding on the processes of firm-level change or adaptation (Bryson and Ronayne, 2014). Whereas, an evolutionary approach shifts the emphasis from theorising the firm as a 'black box', to one in which a firm consists of resources, capabilities and routines that are established over

time to generate value (Boschma and Frenken, 2011; Frenken and Boschma, 2007; Nelson and Winter, 1982; Penrose, 1959).

The EEG approach 'provides a general theory of change while being applicable to specific processes in space and time' (Frenken and Boschma, 2007: 635). It relates and highlights the inter-connections between the processes of firm-level changes (micro dynamics) to sectoral-level changes (meso dynamics) in space (Boschma and Frenken, 2006; Boschma and Martin, 2007). In this study, an emphasis on the firm informs an understanding on the changes of the British manufacturing sector and the UK TT industry, and how UK TT firms are embedded and function in the local and global economy (Boschma and Martin, 2007; Frenken and Boschma, 2007).

The current EEG literature 'is still under construction'; it is theoretically sophisticated but needs to be supported by detailed firm-level empirical studies and current 'empirical applications need to be developed further' (Boschma and Frenken, 2011: 303). This thesis provides a study at the micro-level of how the firm is organised, operates, and develops new routines to compete and learn (Aldrich and Ruef, 2006; Frenken and Boschma, 2007). The current research limitations on understanding the adaptation of manufacturing firms that have remained competitive in a high-cost location, especially UK TT firms, has informed the aims and objectives of this thesis (Table 1.3). The aims and objectives of this study are examined through a detailed comparative analysis of forty TT firms located across the UK. A UK wide study was chosen to develop a representative study of the seventy-six TT

firms identified. Further analysis on the UK TT industry, sampling strategy and access to firms is reviewed in Chapter 3.

Table 1.3: Research Aims and Objectives

Theoretical Aim To apply the evolutionary economic geography approaches to a manufacturing sector in a high-cost location.
Empirical Aim To investigate the adaptation and evolution of UK technical textile manufacturing firms in the UK.
Objective 1 – Chapter 4 To identify the key characteristics of the UK technical textile industry and the adaptation processes of firms to manufacture technical textiles.
Objective 2 – Chapter 5 To explore the interwoven sources of firm-based competitiveness, which enable technical textile firms to maintain their manufacturing systems in the UK.
Objective 3 – Chapter 6 To examine the adaptation of UK technical textile firms routines to develop and implement their firm-based competitiveness strategies.
Objective 4 – Chapter 7 To evaluate the limitations and constraints to firm's routines, which challenge the sustainability of a competitive technical textile manufacturing base in the UK.

This thesis makes a valuable contribution in terms of emphasising the competitive dynamism and changing economic geographies of manufacturing in the UK and elsewhere (Section 2.2). It contributes theoretically to the body of literature on firm-based

competitiveness and EEG (Boschma and Martin, 2007; Bryson *et al.*, 2013; Christopherson, 2013; Essletzbichler and Rigby, 2010; Hoopes *et al.*, 2003). With the exception of Hassink's (2010) study, on the adaptation of traditional textile firms to TT in the Westmünsterland textile region in Germany, this thesis is also the first piece of empirical research in the social sciences on TT. Its theoretically informed findings makes this work of particular interest to academics working in this field, as well as trade bodies and associations of manufacturing and textiles. Moreover, the discussion contained herein is highly pertinent to manufacturing firms based in high-cost locations, for insight into the strategies other firms have developed to remain profitable and competitive. It will also be relevant to policy-makers of reformed manufacturing and industrial policy in the UK, which is emphasising a rebalancing of the British economy towards manufacturing (Livesey, 2012b).

1.5 Summary and Structure of Thesis

This chapter has provided an introduction to the UK TT industry and the theoretical foundation of this thesis. It has highlighted the key research gaps in understanding the adaptation of manufacturing firms based in high-cost locations that have remained profitable and competitive in a global economy (Bryson *et al.*, 2015a; Hudson, 2010; Livesey, 2006). Since the 1960s, the UK textiles industry has suffered from price-based competition, with the majority of firms that were involved in the production of household goods and clothing to move offshore to developing market economies (Dicken, 2011; Gereffi, 1994; Scott, 2006). A small group of 76 firms have maintained their textile manufacturing systems in the UK by adapting to the production of TT. TT is a high value-added segment of the

textiles industry, and is defined as textiles with the addition of technical attributes (Section 1.3). TT has emerged from the innovative interface with other disciplines and extends beyond the textile industry itself, as TT firms engage, interact and provide solutions to a diverse range of industries (Christopherson, 2009; Foresight, 2013; McQuaid, 2005).

The thesis employs an evolutionary approach to investigate the adaptation and competitiveness of UK TT manufacturing firms. This will provide a study on the firm, as the unit of analysis, whilst developing an understanding on the interdependencies between the firm and it's external economic environment (Boschma and Frenken, 2006; Boschma and Martin, 2007). The empirical chapters focus on examining the different adaptation pathways firms undertook to transform to TT, identifying the sources of firm-based competitiveness and investigating UK TT firms routines, and their limitations, which supports the development and delivery of their competitiveness strategies. The research enquiry of this thesis is explored through the following seven chapters:

Chapter Two sets out the theoretical foundation of this thesis. Manufacturing continues to play a fundamental role in the nations' prosperity (Bryson *et al.*, 2008). The UK manufacturing sector is at the beginning of a new industrial revolution driven by the emergence of new manufacturing technologies (Foresight, 2013; O'Sullivan *et al.*, 2013). Innovations in the UK TT industry emphasises this, as firms have eliminated boundaries between textiles and many other disciplines to produce sophisticated TT products (McQuaid, 2005; Quinn, 2010). There has been a renewed interest in the political and

academic debates, which is keen to advance an understanding of manufacturing from pre-to-post industrial worlds (Vanchan *et al.*, 2015). These emerging debates highlight a key research gap to understand the sustainable competitiveness of firms based in high-cost production locations (Bryson *et al.*, 2008; Christopherson, 2011; Hudson, 2010). The chapter develops an understanding on firm-based competitiveness by combining two related and key sets of theoretical perspectives: the Resource-Based View (RBV) of the firm and Evolutionary Economic Geography (EEG). A conceptual framework is developed that blends these two perspectives, upon which to base the analysis and discussion of this thesis.

Chapter Three provides a detailed discussion of the research methodology for this thesis. The primary research design of this thesis is a comparative firm-level analysis of 40 UK TT firms. Qualitative approaches and techniques were utilised to first, obtain rich and detailed accounts of firm daily practices, decision-making and behaviours, and second, to analyse the data for categorisation and connection (Aldrich and Ruef, 2006; Kitchin and Tate, 2000; Valentine, 2005). Semi-structured interviews were undertaken between September 2012 and October 2013, and supplemented by additional intermediary interviews with industrial experts and academics, as well as secondary sources of corporate brochures and websites. An initial challenge to this thesis has been to identify the UK TT sector, due to inconsistent statistical reporting. The identification process of the UK TT sector, sampling strategy and the several measures undertaken to gain access to firms is therefore examined. Significantly, the researcher undertook a three-month industrial placement with the TT trade body, NWtexnet, between April and June 2012 to widen her understanding of the UK

TT industry. This placement enabled the researcher to develop credibility, become an 'insider' of the UK TT industry and negotiate access into a 'tightly knit community' (Sixsmith *et al.*, 2003). The main ethical considerations of the study were research transparency and confidentiality, which was managed by informed consent and confidential strategies. An examination into the validity of the results confirms that the sample of this study is representative of the UK TT population, and the analysis can be generalised to firms in the UK TT industry and used to inform the analysis of other similar sectors (Bryman, 2008; Denscombe, 2010).

Chapter Four identifies the key characteristics of UK TT firms and the adaptation processes of firms to enter into the manufacturing of TT (Research Objective 1). In response to changes in traditional textile competitive dynamics, which revolved around a strong increase in competition from developing market economies, as well as new technological developments in textiles, a group of firms engaged in adaptation processes to reallocate their resources and capabilities into TT. The formation of the UK TT industry highlights the co-evolution of innovation and industry structure in response to changes in TT firm's external economic environments of competition and shifting markets (Martin, 2010). This chapter contributes a detailed analysis on the attributes and evolution of the UK TT industry, and provides context for the subsequent empirical chapters. Significantly, this chapter identifies two periods of adaptation in the UK industry, which are both a response to changing competitive dynamics. The first period revolves around the emergence of the industry in the twentieth century, whereas the second period can be traced to the early

2000s, which has witnessed a further adaptation of firms for sustainable competitiveness. This highlights that further research is required on this second adaptation period of the UK TT industry to develop an understanding on the sources of firm-based competitiveness. The remainder of the thesis focuses on the second adaptation period, in particular the last ten years, as this is evidence base that was accessible to the reader during data collection.

Chapter Five explores the interwoven sources of firm-based competitiveness developed by UK TT firms to maintain their manufacturing systems in the UK (Research Objective 2). This chapter builds upon chapter four, which identified a second adaptation period of UK TT firms that can be traced to the early 2000s, in response to new TT competitors based in low-cost locations (Byrne, 2007; Martin, 2010). It focuses on this second adaptation period, and examines how the competitiveness strategies developed by UK TT firms provides them with inimitable forms of competitiveness. UK TT firms have developed and blended four competitiveness strategies related to cost management and non-price-based strategies, which revolve around competitive advantages of place, innovation and service provision. The strategies all incorporate localised resources and capabilities of the UK TT firms, which has provided them with geographical competitive advantages over competitors located in low-cost locations (EEF, 2014; Foresight, 2013; Schroeder *et al.*, 2002).

The chapter explores the interwoven aspects of firm's sources of competitiveness, and therefore provides a significant contribution to the manufacturing competitiveness literature of how to understand the complexity of firm-based competitiveness (Hoopes *et*

al., 2003). Examination into the competitiveness strategies of UK TT firms emphasises the requirement of flexible innovation and production routines. This suggests that the adaptation of these two types of routines has therefore played a significant and instrumental role in the formation of UK TT firm's inimitable competitiveness (Aldrich and Ruef, 2006; Boschma and Frenken, 2006). Chapter 6 is interdependent to this chapter, as it will examine the adaptation of UK TT firm's innovation and production routines.

Chapter Six examines the adaptation of UK TT firm's routines, which have been adapted to support the development and implementation of firm's competitiveness strategies outlined in Chapter 5 (Research Objective 3). This chapter validates how there are significant interdependencies between UK TT firm's routines and their competitiveness strategies (Boschma and Martin, 2007; Martin, 2010). To implement their competitiveness strategies, which are customer and service focused and revolve around innovative behaviour and practices, UK TT firms have adapted their innovation and production routines (Boschma and Frenken, 2006; Bryson and Taylor, 2010). This chapter identifies the different adaptation processes, which inform the modification of existing and introduction of new routines. These include search processes of organisational learning, to learn of new technologies and develop new ideas and practices (Laursen and Salter, 2006; Maskell and Malmberg, 1999b), and selection processes of experimental learning, to evaluate and test which new ideas can be selected and embedded into their existing routines (Boschma and Frenken, 2011; Essletzbichler and Rigby, 2007; Malmberg and Maskell, 2010). Adaptability, a continual process of change in routines (Martin, 2010; Schamp, 2005), can be restricted

by a firm's path dependency of lock-in situations, which include an established client base, product portfolio and workforce. UK TT firms have developed the capabilities of their employees to successfully implement new and adapted routines, which explores the co-evolution synergies between the capabilities of UK TT firm's employees and the adaptability of their routines (Boschma and Martin, 2010; Rigby and Essletzbichler, 1997).

Chapter Seven evaluates the limitations and constraints to UK TT firm's innovation and production routines, which could challenge the sustainability of a competitive technical textile manufacturing base in the UK (Research Objective 4). The reflexive adaptability of UK TT firm's routines is required to sustain their positive evolution trajectory (Hoopes et al., 2003; Martin and Sunley, 2006). This chapter examines how UK TT firm's adaptability is limited and constrained by three barriers to growth: skill succession, innovative progression and infrastructural support of manufacturing in the UK. These barriers revolve around the change in market strategy by UK firms to adjust to higher value-added TT markets, in response to changing competitive dynamics and commoditization of some TT products.

These advanced markets require firms to consist of a highly skilled labour force, to adopt and employ advanced manufacturing routines and innovation procedures for the development of complex products. Skill succession is the maintenance of skill and expertise capabilities through the transfer of knowledge between workers (Brooke and Taylor, 2005). However, succession management efforts by UK TT firms are undermined by an ageing workforce, significant recruitment barriers of attracting young people into a manufacturing

career (Alliance, 2015; Livesey, 2013) and training challenges, due to the complexity of the skillset required by UK TT firms (Bryson et al., 2013). Significantly, this chapter emphasises how the UK TT industry is associated to the traditional textile industry, as the contraction of the UK textile industry has resulted in reduced infrastructure and disengaged institutional support for firms. The chapter concludes by evaluating the sustainability of a UK manufacturing base for TT firms and investigates how industrial policy and institutional support can assist TT firms to overcome their adaptability barriers.

Chapter Eight concludes the findings of the thesis and evaluates its theoretical contribution. It re-examines the novel firm-level evolutionary approach of this thesis, which emphasises how the micro-behaviour of firms is formative to the evolving economic geographies of manufacturing. It explores the wider contribution this thesis makes to the conceptual and empirical development of the EEG field, by discussing how the main findings of the thesis contribute to the theoretical development of four EEG concepts: adaptation, path-dependence, routines and evolution. This thesis is relevant to policy-makers of reformed UK manufacturing and industrial policies. The chapter explores the implications that this study has on these policies. The chapter concludes by evaluating the research process and identifying potential areas for further research.

2 THE FABRIC OF MANUFACTURING FIRMS COMPETITIVENESS AND EVOLUTION

2.1 Introduction

The theoretical aim of this thesis is to apply evolutionary approaches to a manufacturing sector in a high-cost location (Chapter 1, Table 1.3). The term evolution derives from 'the Latin verb *evolvere* and refers to the processes of unfolding or unrolling' (Hodgson, 2009: 169).[2] Evolutionary approaches emerged within the discipline of economics in the 1970s, in opposition to mainstream neoclassical economics (Essletzbichler and Rigby, 2007), and to develop a fuller understanding of the processes that transform the economy over time (Boschma and Martin, 2007). Since the 1990s, economic geographers have adopted evolution metaphors and terminology from institutional economics, such as 'path dependence', 'learning' and 'lock-in' (Coe, 2011; David, 1985; Martin and Sunley, 2006). Within the last decade, an Evolutionary Economic Geography (EEG) framework has been constructed, which aims to understand the dynamic processes that influence and change the behaviour of firms and the market environment in which they operate (Essletzbichler and Rigby, 2010; Nelson and Winter, 1982; Rigby and Essletzbichler, 1997).

[2] This term was first applied to *Origins of Species.* Evolution was applied to the social sciences in the 1870s to refer loosely to the evolution of language, law and society (Hodgson, 2009).

The aim of this chapter is to develop a conceptual framework, which draws together the findings from a review of the RBV of the firm and EEG literatures, to understand the 'fabric' or foundation of firm-based competitiveness. The integration of these two related theoretical perspectives addresses the current limitations in understanding the competitiveness and evolving economic geographies of manufacturing firms located in a high-cost location, by focusing on the UK TT industry. The EEG approach assists in understanding how the industrial evolution of the UK textile industry to TT, its economic restructuring, transformation and technological progress, is shaped by the micro-behaviour of firms (Boschma and Martin, 2007; Essletzbichler and Rigby, 2007; Nelson and Winter, 1982; Schamp, 2005). The RBV of the firm is the mainstream theory to explain firm-based competitiveness (Hoopes *et al.*, 2003). The EEG approach contributes to the RBV of the firm by emphasising the importance of routines, the organisation and management of resources and capabilities into settled and repeated patterns of behaviour, in the development and implementation of firm's competitiveness strategies and capabilities (Aldrich and Ruef, 2006; Boschma and Frenken, 2006; Martin, 2010).

This chapter is divided into six sections. The first section examines the characteristics of manufacturing in the twenty-first century, and the renewed interest of manufacturing in political and academic debates. The second section integrates the RBV and EEG approaches to conceptualise the firm. The third section adopts the RBV perspective to inform an understanding on the sources of firm-based competitiveness. The fourth section employs the EEG perspective to develop an understanding on how organisational routines,

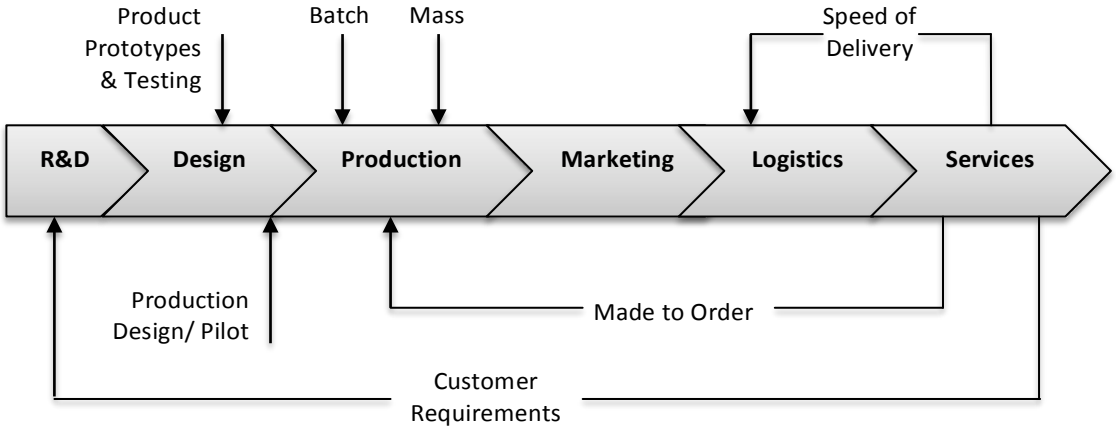
particularly the adaptation and development of new routines, determines the competitiveness of a firm (Frenken and Boschma, 2007; Teece *et al.*, 1997). The fifth section develops a framework of the theoretical foundation of this thesis, upon which to base the research reported in the following chapters. The sixth and final section summarises the main themes of this chapter.

2.2 A New Geography of Manufacturing

The UK reached its peak of manufacturing activity in 1966, when the sector accounted for 35 per cent of Gross Domestic Product (GDP) and employed 8.7 million workers (SCTI, 2002). Employment has been the key measure of manufacturing activity (Dicken, 1982). Academic and political accounts of manufacturing since the 1970s have therefore revolved around the on-going deindustrialisation of the UK (Moretti, 2013) in response to the emergence of international competition (Owen, 1999). Accounts of deindustrialisation emphasise the collapse in manufacturing employment rather than the continuity of manufacturing production (Bluestone and Harrison, 1982; Cohen and Zysman, 1987; Livesey, 2012b; Loch *et al.*, 2007; Moretti, 2013). Firms have increased the technical composition of capital production to increase labour productivity and output (Hudson, 2010). This has meant UK manufacturing activity has declined in terms of employment, but primarily as a result of productivity growth and greater outputs. Between 1985 and 2009, output per manufacturing employee more than doubled (BIS, 2010: 9) and in 2007, before the economic recession of 2008, UK manufacturing output was 28 per cent higher than in 1970; 'in fact, [UK] manufacturing output hit its all-time peak in February 2008' (Davis,

2011: 76). The de-industrialisation argument 'greatly underestimates the prospects for manufacturing' (Fingleton, 1999: 3).

Figure 2.1: The Advanced Manufacturing Process



Source: Adapted from (Livesey, 2006: Figure 2).

Some UK manufacturing firms have transformed themselves to incorporate a wider range of activities, meaning the actual production of a product or component is only one element of the manufacturing process (Foresight, 2013) (Figure 2.1). These firms have become complex organisations. They may outsource one or multiple elements of the manufacturing process, including the production of a product as they focus on the design, branding and marketing of the product (Upton and McAfee, 1996), but are still classified as a manufacturing firm (Bryson *et al.*, 2008). This has led to a fundamental blurring of 'boundaries between what can be identified as a service or a manufacturing firm' (Bryson *et al.*, 2004: 73). The substantial growth in the service sector, or the de-industrialisation of manufacturing employment, can be explained as simply 'an expression of activities re-

classified from manufacturing to services but still functionally linked to manufacturing' (Hudson, 2010: 144).

Since 2008, a new trend has emerged in the geography of production (Bryson *et al.*, 2013). This is reshoring, the return of production activities to high-cost locations and 'the expansion of existing facilities or firms in industries that have been susceptible to offshoring, as well as the attraction of new FDI in those sectors' (Cowell and Provo, 2015: 73). In a recent survey by EEF (2014: 9), between 2010 and 2013, one in six UK-based manufacturers brought production back, to produce products within their own organisations, and the same proportion have switched to a UK supplier from developing market economies. Offshoring decisions were previously based on labour costs, however, as labour costs rise in developing market economies in conjunction with a rise in fuel and transportation costs, firms are now considering the 'total production cost' (Gray *et al.*, 2013). A full cost analysis considers the wider factors associated with fragmented supply chains (Christopherson, 2013; Day, 2014). These hidden costs include concerns over intellectual property embedded in products and processes, quality concerns, supply chain disruptions and advantages of co-locating R&D and production (Christopherson, 2011; EEF, 2014; Foresight, 2013). This reshoring phenomenon is occurring predominately in heavy, bulky goods, such as machinery components, steel, building material and furniture (Walcott, 2011: 6). However, it is also occurring in low volume products, in which labour accounts for a minor proportion of costs, such as TT intermediate components for the automotive, aerospace and construction industries (Bryson *et al.*, 2013).

Manufacturing is at the start of another new industrial revolution. This revolution is firstly driven by this reshoring phenomenon, but a second driver is the emergence of new manufacturing technologies (Bryson *et al.*, 2013). Technological developments include 'new materials, the application of electronics to create new solutions… and the design and development of sustainable products including lightweight products' (Bryson *et al.*, 2013: 52). Composites are a lightweight solution provided by TT. Over half of the Boeing 787 Dreamliner airframe is manufactured from composites, including the fuselage (central body of the aircraft) and wings (Figure 2.2) (Hale, 2006). This is reducing the weight of the aircraft and its subsequent fuel consumption (Bowler, 2014).

Figure 2.2: Material Structure of the Boeing 787 Dreamliner



Source: Hale (2006)

Innovation in TT has pushed the boundaries and eliminated borders between textiles and many other disciplines, such as information technologies, biology and engineering, to produce sophisticated textiles (McQuaid, 2005; TechniTex, 2015a). Process innovations

include three-dimensional weaving, electro-spinning and surface enhancement treatments of atmospheric plasma, laser and nanotechnologies (Macbeth and Miln, 2012; O'Mahony, 2007). Novel product innovations include 'smart textiles' and anti-bacterial TT. 'Smart textiles' incorporate the integration of sensors into textiles (military uniforms) to become a responsive device (monitoring the physiological and health welfare of the soldier), while anti-bacterial fabrics repel and/or kill germs, creating antiseptic environments in hospitals (Quinn, 2010).

2.2.1 A Manufacturing Renaissance in Political and Academic Debates

In recent years, especially since the financial crisis that commenced in 2008, there has been a renaissance, a renewed interest in the political and academic debates on manufacturing (Foresight, 2013; Vanchan *et al.*, 2015). Industrial policy is 'a set of activities which create a favourable environment for business and for adapting production to changing domestic or international demand' (Aiginger, 2007: 300). The British industrial policy has fluctuated over the past 30 years and has not had a specific manufacturing focus (Livesey, 2012b). Successive governments have embraced and promoted a neoliberal regulatory model, which has focused on privatization, financial services and their deregulation, attraction of foreign direct investment, promotion of R&D, and entrepreneurship (Aiginger, 2007; Dicken, 2011; Hudson, 2010; Livesey, 2012b).

The 2008 economic recession centred around failures in the financial system and is associated to political debates that call for a rebalancing of the British economy towards manufacturing (BIS, 2010; Vanchan *et al.*, 2015). In March 2011, the Chancellor of the Exchequer concluded the budget statement by stating manufacturing would play a central role in the UK's economic recovery and that (Vanchan *et al.*, 2015):

> 'We want the words: "Made in Britain", "Created in Britain", "Designed in Britain" and "Invented in Britain" to drive our nation forward – a Britain carried aloft by the march of the makers. That is how we will create jobs and support families' (GOV.UK, 2011).

Since the change in British government in 2010, and from the context of the financial crisis, core industrial policies have emerged in support of a strong and vibrant manufacturing base (Livesey, 2015) (Table 2.1).

Table 2.1: British Manufacturing Policies Since 2010

1.	Funding for catapult centres (originally called technology and innovation centres), with the first catapult established to cover high value manufacturing.
2.	The formation of nine centres for innovative manufacturing to undertake research on strategic areas of importance.
3.	The re-launch of the Manufacturing Advisory Service (MAS) to provide advice to manufacturing companies on productivity and innovation improvements.
4.	The establishment of an international prize in engineering worth one million pounds (now termed the Queen Elizabeth Prize for Engineering).

Source: Livesey (2015: 404)

Similar to the political debates, much of the academic literature 'over the last decade has been on understanding service-based economies, neglecting manufacturing and its effects on the economy' (Bryson *et al.*, 2015b: xv). There has been an emergent academic literature on the new economic geographies of manufacturing (Vanchan *et al.*, 2015). The contributors in this research field have advanced debates and understanding of manufacturing from pre- to post- industrial worlds (Bryson *et al.*, 2015b). These studies focus on the characteristics of manufacturing in the twenty-first century in terms of labour and skills (Kalafsky, 2008; Lowe, 2013; Lowe, 2015; Weller, 2015), design and innovation (Bryson and Rusten, 2011; Cusmano *et al.*, 2010; Hansen and Winther, 2011; Hatch, 2013), and logistics and supply chains (Gereffi and Lee, 2012; Hall, 2015; Walcott, 2011). These literatures emphasise 'how industries and firms are adapting to new technologies and new markets' (Clark *et al.*, 2015: 491).

The renaissance of manufacturing debates initially emerged with studies examining the competitiveness of firms located in developed market economies, in the following specific industries: automotive (Daniels and Bryson, 2002), optics and photonics (Christopherson and Clark, 2007), machine tools (Kalafsky, 2007), locks (Bryson *et al.*, 2008), jewellery and whistles (Bryson and Taylor, 2010), basic metals (Mulhall and Bryson, 2013), clothing (Evans and Smith, 2006), furniture (Walcott, 2011) and carpets (Bryson and Ronayne, 2014). The manufacturing competitiveness research has raised a number of key questions, which require further empirical research (Table 2.2).

Table 2.2: Key Research Enquiries to Understand New Geographies of Manufacturing

	Further Research Enquiry	Academic Source(s)
1.	How has the production process of manufacturing firms changed to incorporate more knowledge and service based activities?	Daniels and Bryson (2002)
1.	How do we define manufacturing in the twenty-first century?	Livesey (2006;2015)
2.	What affect will skills shortages have as manufacturing firms move up the value chain in the twenty-first century?	Kalafsky (2007;2008)
3.	What different types of competition are manufacturing firms experiencing?	Bryson et al. (2008)
4.	Why and how have some manufacturing firms survived and remained competitive and profitable in developed market economies?	Bryson and Taylor (2010)
5.	What are the competitive strategies of firms and how have they been influenced by the global economy and changing geographies of manufacturing?	Hudson (2010)
6.	What are manufacturing firms in high-cost locations comparative advantages and how can they be translated into a sustainable industrial manufacturing base?	Christopherson (2011)

Source: Author (2015)

These enquiries (Table 2.2) highlight a key research gap on understanding how alterations in market conditions, consumer demand and the emergence of new technologies, as well as the resources and capabilities of the firm, affect the competitiveness of manufacturing firms (Bryson and Taylor, 2010; Christopherson, 2011; Hudson, 2010). Furthermore, it emphasises how the adaptation or evolution processes of firms transforming from old and

mature manufacturing technologies and processes to new, advanced and innovative organisational forms needs to be examined (Boschma and Frenken, 2006; Boschma and Martin, 2007; Bryson *et al.*, 2015b; Foresight, 2013; Livesey, 2006). This thesis develops a novel firm-centred approach to understanding sources of competitiveness and the evolving economic geographies of manufacturing by blending the RBV of the firm and EEG literatures. The next section develops a definition of the firm by integrating these two related theoretical perspectives.

2.3 Conceptualising the Firm: Resources, Capabilities and Routines

An evolutionary approach attempts to understand the spatial structure of the economy from the underlying industrial dynamics of firms (Boschma and Frenken, 2006, 2009). This means that the firm is the unit of analysis in EEG rather than the locality (Frenken and Boschma, 2007). To understand how UK TT manufacturing firms develop competitive strategies to survive and thrive in a globalising economic environment, the firm has to be conceptualised (Dicken and Thrift, 1992; Taylor and Asheim, 2001). The firm is the driver of knowledge transfer, innovation and economic change, the site of enterprise, the locus of job and wealth creation and the source of competitive advantage (Taylor, 2006). But it is also an ambiguous entity; it has no accurate definition or precise singular theory (Taylor and Asheim, 2001). Theorising the firm has been attempted 'across a range of disciplines, including economics, economic sociology, and management science' (Taylor, 2009: 173). Within these disciplines, the mainstream theories have been classical and neo-classical, defining the firm as a 'black-box contraption converting price signals from the market into

the outputs of commodities or intangibles without any specification of the particular processes involved' (Maskell, 2001: 330). The emergence of the 'New Economic Geography' in the 1990s led a change in the conception of the firm in economic geography to a socio-economic approach (Rusten and Bryson, 2010; Yeung, 2005). This approach incorporates the 'role of place, space and locality in the development and functioning of firms' (Taylor, 2009: 173). The RBV of the firm and EEG perspectives are related socialised approaches to theorising the firm (Taylor, 2006).

The RBV of the firm defines the firm as a set of resources that are selected and combined into firm-specific capabilities (Taylor, 2009). A resource is an asset that is owned or controlled by a firm, and can be valued and traded (Bryson and Ronayne, 2014: 472). Whereas, capabilities are 'a special type of resource – specifically, an organizationally embedded non-transferable firm-specific resource whose purpose is to improve the productivity of the other resources possessed by the firm' (Makadok, 2001: 389). Capabilities are intangible, not easily observable, and can only be valued or exchanged as part of its complete entity (Hoopes *et al.*, 2003; Taylor, 2006). They include branding, marketing, ownership of registered designs and patents, place-based or country of origin associations, specific skills and internal process and product knowledge (Bryson and Rusten, 2011; Grant, 1996; Wernerfelt, 1984). Capabilities are considered as 'ownership specific advantages' that cannot be readily assembled through markets, which provide firms with advantages over potential competitors (Kogut and Zander, 2003; Teece *et al.*, 1997).

Firms have physical capital resources (site and buildings, machines and equipment, geographic location, access to raw materials, cash and inventory), human capital resources (skills, training, experience, knowledge, character, relationships) and organizational capital resources (formal and informal planning, controlling and coordinating systems, informal relations within the firm, and between the firm and its environment) (Barney, 1991). Firms acquire and develop their assets internally through their inherited site and equipment, their own corporate culture and learning environment, and through the internal social dynamics of the individuals within the firm (Nelson and Winter, 1982; Taylor and Asheim, 2001). Firms also acquire and develop their assets externally through M&As, which enable firms to trade non-marketable resources (Wernerfelt, 1984), and through their network relations (markets, customers, suppliers), broader social environment and local economic systems (Dicken and Malmberg, 2001; Granovetter, 1973; Oinas, 2006; Oinas and Lagendijk, 2005; Yeung, 2005).

Evolutionary perspectives contribute to the RBV of the firm by emphasising how firms consist of organisational routines, the organisation and management of resources and capabilities into settled and repeated patterns of behaviour, which reflects the decision-making and behaviour of firms (Aldrich and Ruef, 2006; Boschma and Frenken, 2006; Cyert and March, 1963; Nelson and Winter, 1982). Routines are based on experiences that are built up and improved upon over time and are to a significant extent idiosyncratic to a firm (Boschma and Frenken, 2009; Frenken and Boschma, 2007). Organisational routines are formed by the individual skills, practiced knowledge (learning by doing) and tacit

knowledge (embodied and difficult to codify) of workers in a firm, which shape the production and decision-making processes (Boschma and Frenken, 2006; Nelson and Winter, 1982). Significantly, firm's routines evolve and adapt over time in response to pressures of the external economic environment, such as changes to UK TT firms competitive dynamics. In this case, firms would develop routines that are heterogeneous and difficult to imitate by competitors (Boschma and Frenken, 2006; Teece *et al.*, 1997).

Blending the RBV of the firm with EEG perspectives conceptualises the firm, and develops an understanding of firm behaviour, as the adaptation and development of organisational routines that blend and combine firm-specific routines into distinctive capabilities (Bryson and Ronayne, 2014; Frenken and Boschma, 2007; Taylor, 2006). The next two sections examine firm-based competitiveness through these two different but related perspectives, before integrating these approaches to develop a conceptual framework (Section 2.6) that will inform an understanding on the competitiveness of manufacturing firms located in a high-cost location.

2.4 Weaving Sources of Competitiveness into a Distinctive Tapestry

The interconnectedness of the global economy has enforced major changes to the nature of firm-based competition (Bryson and Taylor, 2010) as manufacturing and export capabilities have been 'dispersed to an unprecedented number of developing as well as industrialised countries' (Gereffi, 2005: 163). First, there has been a substantial growth in

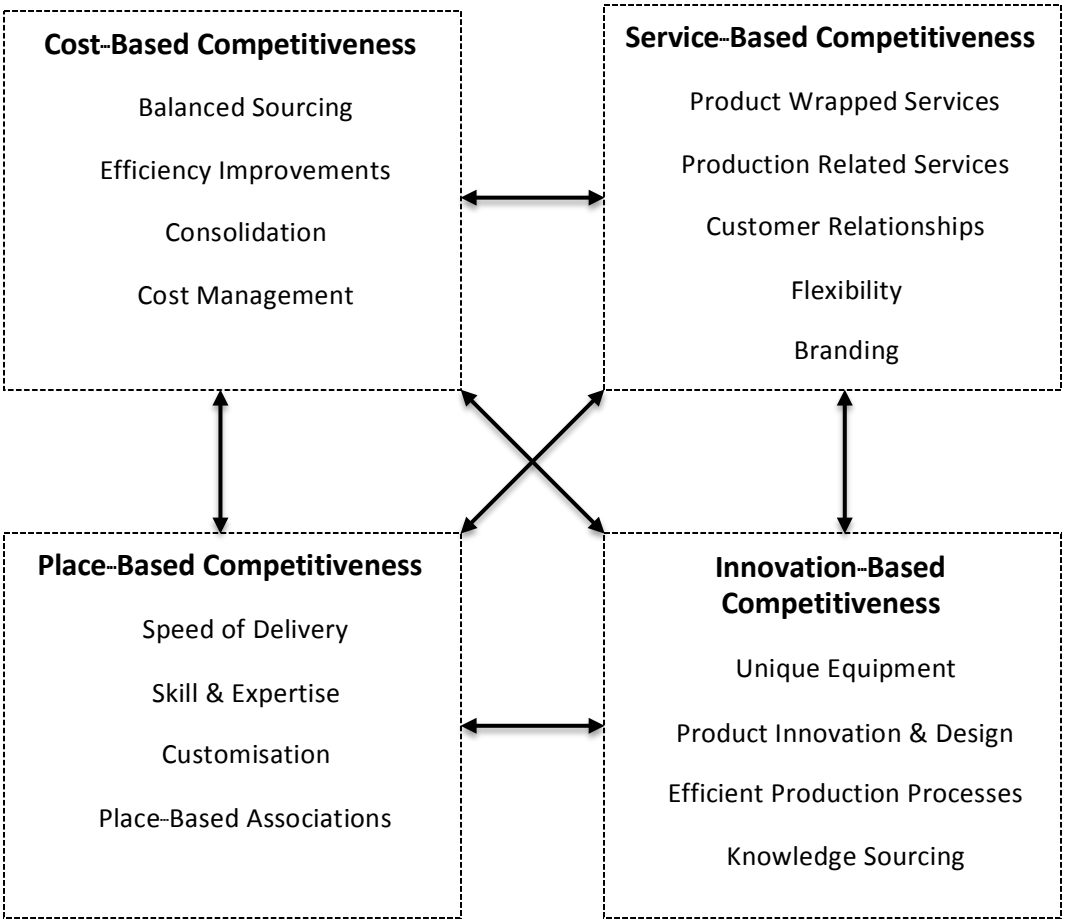
firms located in developed market economies experiencing price-based competition from new competitors located in low-cost production locations. Second, firms are experiencing price-based competition from 'virtual' manufacturers that outsource the production component of the manufacturing process to low-cost producers (Bryson and Taylor, 2010). Price-based competition derives low-profit margins and has low barriers to entry, as any firm can replicate price driven approaches (Bryson *et al.*, 2008; Daniels, 2005). To maintain profitability and competitiveness in developed market economies, UK manufacturing firms have had to focus on *how* they compete, developing alternative strategies to competing on the basis of price (Hudson, 2010; Porter, 2000).

The RBV of the firm has emerged as the mainstream theory to explain firm-based competitiveness (Barney, 1991; Penrose, 1959; Wernerfelt, 1984). The RBV of the firm primarily addresses why the performance of firms within the same sector varies over time (Hoopes *et al.*, 2003). It assumes a firms strategy is intended to achieve some form of Sustainable Competitive Advantage (SCA), which will enable the firm to earn economic rents or above average returns (Barney, 1991; Schroeder *et al.*, 2002). To confer SCA, resources and capabilities must have four attributes: Value, Rarity, Isolation from Substitution and Inimitability (Barney, 1991; Eisenhardt and Martin, 2000; Hoopes *et al.*, 2003). These attributes enable firms to be distinctive, set apart from the competition and make it more difficult for competitors to catch up or copy (Taylor and Asheim, 2001; Wernerfelt, 1995).

Value and inimitability are the two most important attributes, as 'rarity by itself does not necessarily create value' (Bryson and Rusten, 2011: 67) and only exists if competitors cannot imitate a firm's products and processes (Hoopes *et al.*, 2003). All firms are exposed to various forms of copying behaviour, for example, a product designed and developed by Nike one year may be copied by rival companies the next (Bryson and Taylor, 2010). It is critical for firms to deploy inimitability strategies 'to prevent competitors from imitating their products and processes' (Bryson and Taylor, 2010: 588). This is achieved through firms weaving together their own unique sources of competitive advantages, attributes and strategies into a distinctive tapestry, providing them with differentiation that is difficult to copy by their competitors (Bryson *et al.*, 2013).

The competitiveness strategies of firms, identified in the current manufacturing literature, can be categorised into four key themes: cost-, place-, innovation- and service-based competitiveness (Figure 2.3). Each competitiveness category has multiple strategies within it, which are combined to create purposive interwoven competitive weapons (Rugman and Verbeke, 2002). For example, J Hudson & Co. (Whistles) Ltd, in Birmingham, West Midlands is the oldest and largest manufacturer of whistles in the world and has combined strategies related to heritage, brand, innovative sound solutions and 'made in England' associations (Bryson *et al.*, 2013).

Figure 2.3: Firm-Based Competitiveness: A Non-Linear Process of Interwoven Strategies



Source: Author (2015)

Non-price-based competitiveness strategies provide firms with inimitability based not on price, but on other factors of innovation, quality, service, customisation, design, place-based associations, branding and heritage (Bryson and Rusten, 2011; Bryson and Taylor, 2010; Bryson *et al.*, 2008). A blend of cost-based competitiveness, the appropriate cost control and reduction of production costs, with non-price-based strategies permits manufacturing to continue in high-cost locations (Bryson and Ronayne, 2014). This blend of

strategies enables firms to afford to operate in the UK and maintain profit levels, as well as develop product differentiation to competitors (Mulhall and Bryson, 2013). Firms will combine strategies in different ways to develop inimitable and sustainable competitiveness (Bryson and Taylor, 2010). These strategies are therefore interlinked and cannot be studied in isolation to fully understand firm-based competitiveness. This section has a holistic structure and the following four sub-sections examine the sources of firm-based competitiveness within each categorised theme (Figure 2.3).

2.4.1 Cost-Based Competitiveness

Globalisation has resulted in firms located in high-cost locations experiencing price-based competition from firms located in low-cost locations (Bryson and Taylor, 2010). There are significant price and cost differentials of factor inputs (raw materials, labour, capital) between firms located in different locations, which highlights how geography influences and determines firm-based competitiveness (Mulhall and Bryson, 2013; Walcott, 2011). The UK has a higher cost base due to its localised factor inputs of labour, land, utilities, taxes and duties (Christopherson and Clark, 2007; Dicken, 2007). Manufacturing firms located in developed market economies find it difficult to compete on the basis of price with low-cost economies (Bryson *et al.*, 2008). Research on the competitiveness of manufacturing firms has focused on non-price-based sources of competitiveness. Strategies include customisation by lock manufacturers in the West Midlands (Bryson *et al.*, 2008), skills and expertise development by the photonics industry in Rochester, New York (Christopherson, 2009), provision of services by Rolls Royce Aerospace (Neely, 2008) and continuous product,

production and marketing innovation by GlaxoSmithKline (Livesey, 2006). Cost-based competitiveness, the appropriate cost control and stripping of costs, is still critical (Bryson and Ronayne, 2014; Mulhall, 2015). Cost control enables firms to be resilient and adapt to changing cost structures of factor inputs, to maintain profit levels and viability to manufacture in the UK (Mulhall and Bryson, 2013).

Firms are employing cost-based competitiveness through strategies of balanced sourcing, consolidation through mergers and acquisitions (M&A) and downsizing, and efficiency improvements. Balanced sourcing involves outsourcing some elements of the production process to a sub-contractor to develop a blended production system (Cusmano *et al.*, 2010; Stratton and Warburton, 2003; Tokatli, 2008). To manage costs, some firms outsource the 'labour-intensive component production and final product assembly fabrication' to low-cost locations, whilst retaining certain production activities in the UK (Hudson, 2010: 143). The production process of a product can be organised over different geographical scales to capitalise on place-based differential competitive advantages of costs and where value can be added (Bryson, 2007; Bryson *et al.*, 2004; Dunning, 1998). This has been exemplified explicitly by the textile and clothing industries. Manufacturing firms of the Italian brand Gucci, the US brand Levi (Dicken, 2007), and British brand Burberry (Tokatli, 2012), have all moved their production activities to low-cost locations to engage in developing their brand, design capabilities, and manage the delivery of their services (Bryson and Taylor, 2010; Evans and Smith, 2006; Pickles and Smith, 2011; Scott, 2002).

The second cost-based strategy is consolidation, which is employed by firms to increase efficiency and competitiveness. It occurs through M&As and downsizing (Bryson and Ronayne, 2014; Dicken, 2007). M&As are a rearrangement of industrial assets between firms 'to increase overall efficiency without necessarily creating additional productive capacity' (Bryson *et al.*, 2008: 178). The UK carpet industry has a long history of M&As, due to a chronic over-capacity of firms in the UK that struggled against the increase in low-cost imports from overseas competitors (Burton, 2005). This enabled the remaining firms to increase their production capabilities and retain established brands by acquiring firms but closing the manufacturing production unit (Bryson and Ronayne, 2014). The Headlam Group, Birmingham (UK) was formed in 1992 through the acquisition of failing carpet firms located across Europe (Headlam, 2011). The firm owns over 40 brands, which are distributed through a shared warehouse and distribution infrastructure, but manufacturing is outsourced (Bryson and Ronayne, 2014).

Further cost management has involved firms employing capital intensive strategies of re-organising and improving existing manufacturing systems to be more efficient, responsive and quality aware (Bair and Gereffi, 2003; Humphrey and Schmitz, 2000; Inman *et al.*, 2011). Manufacturing processes can become increasingly efficient by mechanisation and automation of low-skilled and labour intensive capital production tasks, which increases labour productivity and enables firms to reduce and manage the size of their workforce and consequently labour costs (Bryson *et al.*, 2008; Florida, 1996; Hansen *et al.*, 2013; Hudson, 2010). This is illustrated by the automotive industry in Europe, which has automated and

robotized the vast majority of their production processes (Bailey *et al.*, 2010; Dunford, 1986; Pavlínek and Ženka, 2010b). Similarly, the surfboard industry has automated manufacturing processes with CAD programs, to mass produce and expand sales of surfboards by raising productivity and standardisation (Warren and Gibson, 2015).

Cost-based strategies are important for firms to employ, but in isolation these strategies do not provide firms with inimitability or sustainable competitiveness, as they could eventually be undermined by price-based competition from low-cost producers (Barney, 1991; Bryson and Taylor, 2010; Bryson *et al.*, 2008). Cost-based competitiveness has to be blended with non-price-based strategies, which are examined in the following three sections, for inimitable, sustainable and strong firm-based competitiveness (Bryson and Ronayne, 2014; Hudson, 2010).

2.4.2 Place-Based Competitiveness

Global and local economic geographies challenge the competitive and sustainable localisation of manufacturing activities in the UK (Bryson and Taylor, 2010; Hudson, 2010). Manufacturing in the UK, a high-cost production location, challenges firm's competitiveness, but it also informs and centres their non-price-based strategies (Mulhall and Bryson, 2013). Firms have developed place-based resources to compete with, which are 'sticky' to their geography, requiring proximity to the firm and cannot be obtained from another location (Bryson *et al.*, 2008). These resources include regional based resources and ownership

specific capabilities, which provide firms with advantages over potential competitors (Kogut and Zander, 2003). A recent survey by EEF (2014) stated the most important sources of firm-based competitiveness are product quality, customer service and a strong record of on-time delivery. All of these competences reveal a growing importance in locality and a greater emphasis on firm's locally proximate assets. Place-based strategies include geographical advantages of logistics and expertise, which are making it increasingly possible for the UK to compete with lower cost locations (Bryson *et al.*, 2008; Foresight, 2013).

Logistical strategies involve firms competing on delivery times and nearness to market for speed and ability to co-produce products (Bryson and Taylor, 2010). Speed of delivery is providing UK firms with a competitive advantage over low-cost competitors, as they cannot physically offer the same level of responsiveness due to their geography (Bryson and Taylor, 2010; EEF, 2014). These proximity advantages have been utilised by apparel manufacturing firms in New York and Southern California, which have survived and remained competitive in a high-cost location, by providing a quick turnaround for replenishing fashion items for nearby retailers (Abernathy *et al.*, 2006). Nearness to market and co-location to customers is a key source of competitiveness to deliver inimitable strategies of customer services, co-production and customisation (Gereffi and Lee, 2012; Loch *et al.*, 2007). Both the lock and jewellery industries in the West Midlands, UK, provide bespoke and commissioned products that are co-produced between the manufacturer and customer to determine design, properties and functions, for example locks designed for the visually impaired

(Bryson and Taylor, 2010; Bryson *et al.*, 2008). Co-production between the customer and the manufacturing firm requires close dialogue and proximity for daily conversations and product development meetings (Bryson and Taylor, 2010; Loch *et al.*, 2007).

The location of manufacturing firms in the UK was traditionally based on the availability of factor inputs (land, raw materials and labour), this led to the development of specialised industrial centres, as firms tended to co-agglomerate to access local assets (Bryson *et al.*, 2013; Gabe and Abel, 2012). This is common for the mature manufacturing industries of textiles and metals, chemicals and engineering (Bryson *et al.*, 2013; Fowler, 2003). The development of skills and expertise, which are difficult to replicate or transfer, is an imperative competitive strategy that is building on firm's existing assets (Bryson and Taylor, 2010; Christopherson and Clark, 2007).

In advanced manufacturing industries, firms require a complex and highly skilled labour force to operate the latest manufacturing equipment and implement efficient production processes, to meet the demand for more sophisticated products and services (Christopherson, 2011; Christopherson and Clark, 2007; Kalafsky, 2008). Firms are increasingly competing on their expertise, to innovate and co-produce with suppliers and customers, by demonstrating their specific technical knowledge and their capabilities to understand customer requirements to develop increasingly complex products (Bryson *et al.*, 2008; Foresight, 2013; Hansen *et al.*, 2013). Manufacturing firms core competencies have become tied to their employees, which are less mobile, spatially inflexible and difficult to

move (Pickles & Smith, 2011; Storper and Walker, 1983). This makes it difficult for firms 'to transfer knowledge embodied in labour from one place to another' (Aoyama *et al.*, 2011b: 15). Location has therefore created a 'stickiness' of immobile resources and capabilities to UK manufacturing firms, which is contributing to their inimitability and competitiveness (Christopherson and Clark, 2007).

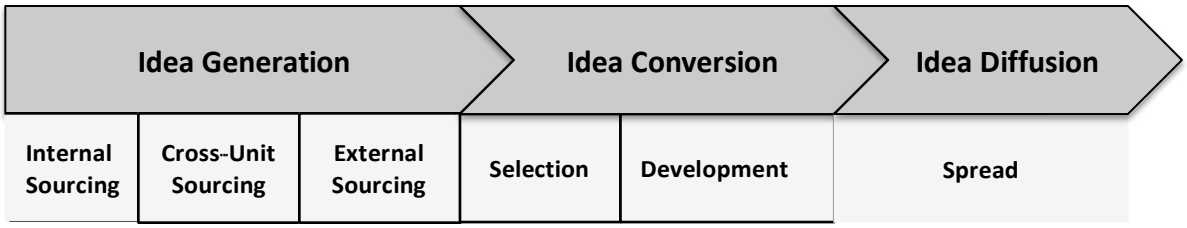
2.4.3 Innovation-Based Competitiveness

Innovation underpins firm-based competitiveness strategies, as it ensures a 'firm's competitive position is resistant to imitation or inhibits the speed by which imitation can take place' (Maskell and Malmberg, 1999b: 176). For example, by the time rival companies have copied Nike products, Nike will have introduced a new product (Bryson and Taylor, 2010). Innovation therefore, enables firms to be agile, introducing a continuous stream of new, improved or redesigned products and services, and develop efficient production processes for SCA in a global economic environment (Dicken, 2011; Kakkad, 2009). Innovation is 'the creation and diffusion of new ways of doing things' (Dicken, 2011: 76). Previously, innovation was measured by R&D activities and science-based technological developments (Bunnell and Coe, 2001). Nowadays, innovation is more broadly defined and involves the development of new or significant improvements in all areas of manufacturing: product, process, design, organisation, market behaviour, or services (EEF, 2013; Sundbo, 1995). A larger proportion of a firm's production time is dedicated to operations, the development of inimitable manufacturing processes (Bryson and Taylor, 2010). This is important to ensure that a firm's production process is difficult to replicate by competitors,

as well as enabling firms to improve their operative processes by increasing quality, and reducing costs and lead times (Bryson and Taylor, 2010; Loch *et al.*, 2007).

The Innovation Value Chain (IVC) conceptualises firm-based innovation into three stages, with six inherent tasks that are each a link in the chain (Figure 2.4) (Hansen and Birkinshaw, 2007). First, firms source different types of knowledge necessary for innovation; this may be internal to the firm, across departmental divisions or through external linkages (Roper *et al.*, 2008). There are two types of knowledge: codified knowledge that is expressed in documents, blueprints and software, and tacit knowledge, which is embodied in people and technical systems, and virtually impossible to make explicit and communicate to others through formal mechanisms (Bunnell and Coe, 2001; Dicken, 2011). Second, firms have to select which ideas will be developed, and transform this knowledge into new products and processes (Hansen and Birkinshaw, 2007; Roper *et al.*, 2008). The last stage involves firms exploiting their innovations through 'product creation and the generation of added value through commercialisation' (Love *et al.*, 2011: 1440).

Figure 2.4: Innovation Value Chain



Source: Adapted from Hansen and Birkinshaw (2007)

The main resource of the firm, which facilitates their innovation activities and capabilities, are its own people (Kogut and Zander, 1992). Firms will look for creative sparks amongst their own employees for knowledge and ideas, as 'they have a pretty good sense of what's close at hand' (Hansen and Birkinshaw, 2007: 3). Firms can encourage the innovative capacity of their employees through education and training, but more importantly through operating an open and flat organisational structure with strong employee involvement in problem-solving and development projects (Arrow, 1962; Nelson and Winter, 1982; Schroeder *et al.*, 2002; Taylor, 2006). Encouragement of employee interaction and cross-unit collaboration develops insight and knowledge from different parts of the same company (Gertler, 2003; Hansen and Birkinshaw, 2007). The mobility of labour, from one firm to another, changes the internal knowledge pool of the firm (Power and Lundmark, 2004). Employees have their own individual skill set, frame of mind and embodied tacit knowledge, which lead to new ideas and approaches to problem-solving and developments. Boschma *et al.* (2009: 170) state 'the inflow of new employees with skills that are related but not similar to the existing knowledge base is the most relevant for the performance of firms'.

Asheim and Isaksen (2002: 77) study on shipbuilding, mechanical engineering and electronics industries in Norway, explains how firms need to exploit both place-specific local resources, as well as external, world-class knowledge to strengthen their competitiveness. External resources to the firm include linkages to customers, suppliers, consultants, competitors, research centres and universities (Roper *et al.*, 2008). Firms

utilise these external resources to tap into divergent knowledge bases, access facilities, equipment and skills, as well as spread the cost and risk in developing new technologies (Hansen and Birkinshaw, 2007; Laursen and Salter, 2006; Malmberg *et al.*, 1996; Saxenian, 1991). Suppliers often have design and technical expertise to assist in product and process improvements, whereas customers engage in co-innovation with the firm as partners to co-produce products (Asheim and Isaksen, 2002; Kakkad, 2009; Schroeder *et al.*, 2002). Bryson and Rusten (2011: 195) state how 'products are not just created by firms and purchased by end consumers – but products are in a continual process of becoming and this process is driven by complex interactions between producers and consumers'. In addition, firms acquire knowledge 'spill overs' from labour mobility, social ties between employees of different firms, and by 'being there' at industry events and trade shows (Asheim and Isaksen, 2002; Gertler, 1995; Granovetter, 1973; Power and Lundmark, 2004; Simmie, 2004; Storper and Venables, 2004). Significantly, developments in information and communication technologies enables industry and technology updates to be instantly accessible through the internet and social media sites of LinkedIn, Twitter and Facebook (Castells, 2003; Papacharissi, 2009).

Innovation is a key competitiveness strategy as it enables firms to thrive in difficult global markets by developing new products, new markets and customer bases untouched by foreign competition, and therefore (at least theoretically) escape price driven competition (Christopherson and Clark, 2007; Glasmeier *et al.*, 1993; Kalafsky, 2007). UK manufacturing firms are innovating. A survey by EEF in 2013 revealed that 96 per cent of firms are

engaging in some form of innovation activity (EEF, 2013). This section has introduced how firms innovate and its strategic role in supporting firm-based competitiveness, but further enquiries remain to understand innovation routines and processes employed by firms. Future research on firm-based competitiveness needs to focus on the following enquiry, 'where does the innovative event, the eureka moment actually take place and how is it developed from an idea to a prototype?' (Ward, 2013). This 'moment' might be a process related to client-based interactions, which occur in the local delivery of services, the next section explores the fourth strategy of service-based competitiveness.

2.4.4 Service-Based Competitiveness

Manufacturing firms are adapting to combine cost control with non-price-based strategies to compete on the basis of inimitability or product differentiation, where firms seek to produce different products with individual characteristics so that each product is an imperfect substitute for competing products (Barney, 1991; Bryson and Rusten, 2011; Bryson *et al.*, 2008; Hoopes *et al.*, 2003). Neely (2007: 2) suggests to achieve this, 'manufacturing firms can rarely remain as pure manufacturing firms. Instead they have to move beyond manufacturing and offer services and solutions, delivered through products'. This includes more customer-focused services of customisation, co-innovation, services 'wrapped around' products (servicing and aftercare), flexibility in production and logistics, and providing a manufacturing experience (Bryson *et al.*, 2013; Daniels and Bryson, 2002; Gebauer *et al.*, 2011; Rusten and Bryson, 2010). Firms have never been pure manufacturing firms, as they have always had service functions as part of their manufacturing processes in

terms of design, marketing, testing, procurement and logistics (Neely, 2008). However, it is service expertise and processes that are increasingly determining the economic value and competitiveness of manufacturing firms in developed market economies (Bryson and Taylor, 2010; Daniels and Bryson, 2002; Gebauer *et al.*, 2011; Loch *et al.*, 2007). Rolls Royce offer a total care package, which is responsible for risk and maintenance of their aero-engines, and in 2009 the company claimed that 49 per cent of its revenue was derived from its services (Foresight, 2013; Neely, 2008).

Manufacturing firms are becoming increasingly complex, as advanced and technologically sophisticated products require an increasing blending of manufacturing, production and product-related services (Bryson *et al.*, 2004; Daniels and Bryson, 2002; Livesey, 2006). Hybrid products are a key example of this, which depend on manufacturing inputs to be produced and function, but also contain embedded services that 'may come over the web in the form of software upgrades or content or via distributed service centres' (Bryson *et al.*, 2013: 14). For instance, the American firm Apple produce the iPod (the product) and provide the embedded software application iTunes (the service) for consumers to manage music, films and TV programs stored on the iPod, as well as the provision of upgrading the iPod (Rusten and Bryson, 2010). Personalisation is becoming increasingly important with the provision of customised services to each consumer, which support or complement products by modifying product configurations or service support, and are responsive, flexible and provide solutions to customer needs, for example adjusting delivery times and frequency (EEF, 2014; Foresight, 2013; Gebauer *et al.*, 2011; Loch *et al.*, 2007).

Services are a strategic source of firm-based competitiveness, as the delivery of services is determined by how they are managed by each firm, meaning the development and execution of services will differ from firm to firm, creating firm uniqueness or distinction (Bryson and Taylor, 2010; Penrose, 1959). Service-based competitiveness strategies are associated to innovation and place-based competitiveness (Section 2.3.2 and 2.3.3). Co-production and co-innovation enters firms into long-term contracts and establishes long-term relationships with consumers, which can increase the service provision and level delivered (Foresight, 2013; Gebauer *et al.*, 2011; Neely, 2008). Service strategies are connected to place-based strategies as some service elements have to be delivered locally and close to market, which becomes difficult or too expensive to imitate by a competitor located in a low-cost location (Bryson and Taylor, 2010). Bryson *et al.* (2013: 16) emphasise further research is required to explore the service inputs of advanced manufacturing firms and how they are becoming an increasingly essential part of hybrid products.

This section employed the RBV of the firm to identify the sources of firm-based competitiveness. The RBV of the firm explains how competitiveness is idiosyncratic to the firm (Hoopes *et al.*, 2003), due to firms developing a unique blend of cost-based strategies with non-price-based strategies (Bryson *et al.*, 2008; Mulhall and Bryson, 2013). Firms combine strategies in different ways to develop distinctive capabilities that provides them with SCA and inimitability against competitors (Barney, 1991; Schroeder *et al.*, 2002). Firms adapt their capabilities and competitiveness strategies through the adoption or development of new routines, in response to changes in their competitive dynamics

(Boschma and Frenken, 2006, 2009, 2011; Nelson and Winter, 1982). The next section employs the EEG perspective to examine the adaptation of routines and how this influences the competitiveness of a firm.

2.5 Evolutionary Competitiveness: Adaptation of Routines

The economy is in a constant flux of 'creative destruction' (Schumpeter, 1942); 'every day, new firms, new products, new technologies, new industries and new jobs are added to the economy, whilst old firms, products, technologies, industries and jobs disappear' (Boschma and Martin, 2007: 537). This flux introduces pressure in firm's external economic environments, which include new types of competition, commoditization of existing products through price-based competitiveness, introduction of new products in the market, changes in product requirements by consumers, and new technological developments in materials and processing equipment introduced by suppliers (Martin, 2010; Martin and Sunley, 2010). To Boschma and Frenken (2006: 278) 'organisations compete on the basis of their routines', as these pressures and in particular the ever-shifting markets and competitive environments, demand firms to respond by the adaptation and development of new routines (Martin, 2010).

Adaptation is the reallocation of firm's resources and capabilities to new organisational forms (Chakravarthy, 1982; Martin and Sunley, 2006). Adaptation is a continual change in firm's routines, which may be gradual or rapid, and enables firms to survive the different

pressures in their external economic environments (Martin and Sunley, 2010). A firm's speed of adaptability or success in adjustment to 'market' (Schamp, 2005) will vary from one firm to another, as some will survive and thrive whilst others will fail, depending on a firm's individual path trajectory (Martin, 2010).

Routines can both enable and constrain the future behaviour of firms (Bryson and Ronayne, 2014), as developmental trajectories of firms are both path dependent and path evolving (Martin, 2010). Path dependence is the current outcome of firm behaviour and decision-making that is a consequence of previous decisions, events and investments (Boschma and Frenken, 2006; Martin and Sunley, 2006). Martin and Sunley (2006) summarise the key defining characteristics of path-dependency as an inability for a system, institution or firm to shake free of their history. Path dependency can restrict a firm's capacity for change and capability to adapt their routines, which leads them into a negative 'lock-in' (Martin and Sunley, 2006). The concept 'lock-in' emphasises how firms can be 'locked' or stuck on an existing and inferior path even though more efficient alternative paths are possible (Martin, 2010; Martin and Sunley, 2006). Firms can lack the adaptability to evolve an existing or establish a new path because of an established workforce, capital, management team, and patterns of behaviour, which are limiting their learning capabilities to generate or adopt new technology (Boschma and Lambooy, 1999). This can lead to relative or even absolute economic decline, as highlighted by the coal and steel industries in Ruhr in the former West Germany when they became 'locked-in', as firms became inflexible, unable to innovate and

ultimately unable to respond to new forms of competition (Grabher, 1993; Martin and Sunley, 2006).

A firm's heritage, historically grown resources and learned routines all make up its individual path of competencies (Schamp, 2005). The economic environment of firms introduces external pressures, which tests the reflexive adaptation of the firm to produce new routines and avoid 'lock-in' (Martin, 2010). A firm's trajectory is shaped by its knowledge base and decision-making of how they learn, use existing resources and creating new resources (Bathelt and Glückler, 2003; Rigby and Essletzbichler, 1997; Schamp, 2005). A firm's dynamic capabilities therefore may enable it to learn and innovate, and in doing so produce new routines, which allows their trajectory to be path evolving (Boschma and Frenken, 2006; Bryson and Ronayne, 2014). Evolving paths, defined as new paths of industrial and technological developments that emerge out of old ones (Martin, 2010), can enable firms to diversify to a new product-market portfolio. This is significant, as a critical aspect of competitiveness involve a firm's core decision on its product-market portfolio (Bryson and Ronayne, 2014; Penrose, 1959).

Firms alter their routines through trial and error, incremental changes, learning by networking, copying and imitation, recruiting employees from competitors and through M&As (Boschma and Frenken, 2006; Boschma and Martin, 2010). This depends on firms 'absorptive capacity' to new ideas and practices, from their local search processes for better technologies (Aoyama *et al.*, 2011a; David, 1985; Martin and Sunley, 2006; Rigby and

Essletzbichler, 1997). Bryson *et al.* (2013: 25) state it is 'important to appreciate that an established or even mature industry can be transformed through the application of new technologies and innovations'. The Rochester region, New York, has been the home to the inter-related industries of optics, imaging and photographic supplies since the 1900s (Christopherson and Clark, 2007). The region had large transnational corporations (TNCs), Eastman Kodak, Xeiox and Bausch and Lomb, which made investments in university and engineering programmes. These employers left the region in the 1970s, but the past investments, as well as pre-existing personal networks, technical skills and market knowledge, enabled a new generation of over one hundred small and spin-off firms to be established (Christopherson, 2009). Since the 1980s, these spin-off firms set up and diversified to produce sophisticated and intermediate components, and are now identified by their technology – photonics - rather than the traditional end products of the industry – optical, imaging and photographic equipment (Christopherson and Clark, 2007; Martin, 2010). Photonics are now used in many different industries than just one, for example, sensors to measure the changes in heat and light used in all kinds of robotic devices (Christopherson, 2009).

The photonics industry in Rochester highlights how local spin-off firms diversified to new markets, which enabled a new and emergent industrial development path to evolve (Fornahl *et al.*, 2012). This was achieved by firms utilising their path dependence processes of routines and competences inherited from previous parent firms, in combination with learning to foster new technology and launch new products and processes (Foresight, 2013;

Martin, 2010). However, the formation of a new industrial path is not always as strongly connected. As Fornahl *et al.* (2012) explain in their study on the role of the shipbuilding industry in the development of a new industrial path of offshore wind energy in Germany. They state that 'in the same industry there may be a technological break or change, or the other way around, the same technology may play a role in different industries' (Fornahl *et al.*, 2012: 841). Further empirical research is needed to develop a richer understanding of how firms develop, adapt and challenge existing routines (Schamp, 2005) to avoid becoming 'locked onto development paths that lose dynamism… and in effect are able to 'reinvent' themselves through successive new paths' (Martin and Sunley, 2006: 395).

This section employed the EEG perspective to develop an understanding on how firms compete on the basis of their routines (Boschma and Frenken, 2006). The formation of routines is influenced by resources internal to the firm, and changes in their external economic environment, for example technological change, new markets, policy changes or increasing competition (Boschma and Frenken, 2006; Christopherson and Clark, 2007; Frenken and Boschma, 2007). The adaptability of routines can become limited and constrained by certain factors, for example path dependency (Martin and Sunley, 2006). A routine enables the firm to implement and deliver a certain economic behaviour that can become a source of competitiveness, for example developing efficient and flexible production processes (Hudson, 2010; Inman *et al.*, 2011), a highly skilled workforce (Christopherson and Clark, 2007), or regular product and consumer focused innovation routines (Bryson and Taylor, 2010). The sustainable evolution of firms, meaning to sustain

an evolving and positive trajectory, depends on firms continually assessing and challenging their routines, to provide a continuous 'loop' of adaptable routines to inform competitiveness (Hoopes *et al.*, 2003; Martin, 2010; Schamp, 2005). To understand the competitiveness of manufacturing firms in a high-cost location, a focus on firm's resources and capabilities needs to be combined with a fuller understanding on routines. The next section combines the RBV of the firm and EEG approaches to develop a blended theoretical framework that conceptualises firm-based competitiveness.

2.6 E-RBV Framework: Understanding the Complexity of Competitiveness

To inform an understanding on the foundation of firm-based competitiveness of manufacturing firms located in a high-cost location, this chapter has begun to blend or combine the RBV and EEG theoretical approaches. The RBV of the firm provides an understanding on how firms consist of resources that are combined into firm-specific capabilities to develop inimitable competitiveness strategies (Barney, 1991; Bryson and Taylor, 2010; Taylor, 2009). The EEG perspective contributes another dimension and further explanation to the behaviour of the firm and its competitiveness, by emphasising how the firm organises its resources and capabilities into organisational routines (Aldrich and Ruef, 2006; Boschma and Frenken, 2006; Nelson and Winter, 1982). These routines adapt over time in response to pressures in firms external economic environments (Martin, 2010). The blend of these two approaches provides an explanation on the sources of firm-based competitiveness, as well as the firm-centred process of adapting organisational

routines, to develop distinctive capabilities and inimitable competiveness strategies (Table 2.3).

Table 2.3: Blended Theoretical Approaches to Understand Firm-Based Competitiveness

Theoretical Approaches	RBV of the Firm	EEG	Evolutionary-RBV
The Firm	Defines the firm as a set of resources combined into firm-specific capabilities.	Views the firm as a site of organisational routines: the management of resources and capabilities into settled and repeated patterns of behaviour.	Conceptualises the firm as a site of organisational routines, which are developed and adapted by the processes of blending firm-specific resources or assets into distinctive capabilities.
Firm-Based Competitiveness	Competitiveness is idiosyncratic to the firm, and inimitability is achieved through the development and blend of inter-linked strategies related to cost, place, innovation and services, which consist of firm-specific resources and distinctive capabilities.	Firms compete on the basis of routines. Firms adapt their routines in response to pressures in their external economic environment. The adaptability of firm's routines is influenced by path dependency and determines the development and implementation of firm's competitiveness strategies.	Firms consist of distinctive capabilities and implement inimitable competitiveness strategies through the adaptation of existing or development of new routines, which are idiosyncratic to the firm.

Source: Author (2015)

The integration and blend of the RBV of the firm and EEG theoretical perspectives has developed and contributed a new and novel conceptual approach to the EEG field: an Evolutionary-Resource-Based View of the firm (E-RBV) framework (Figure 2.5). This

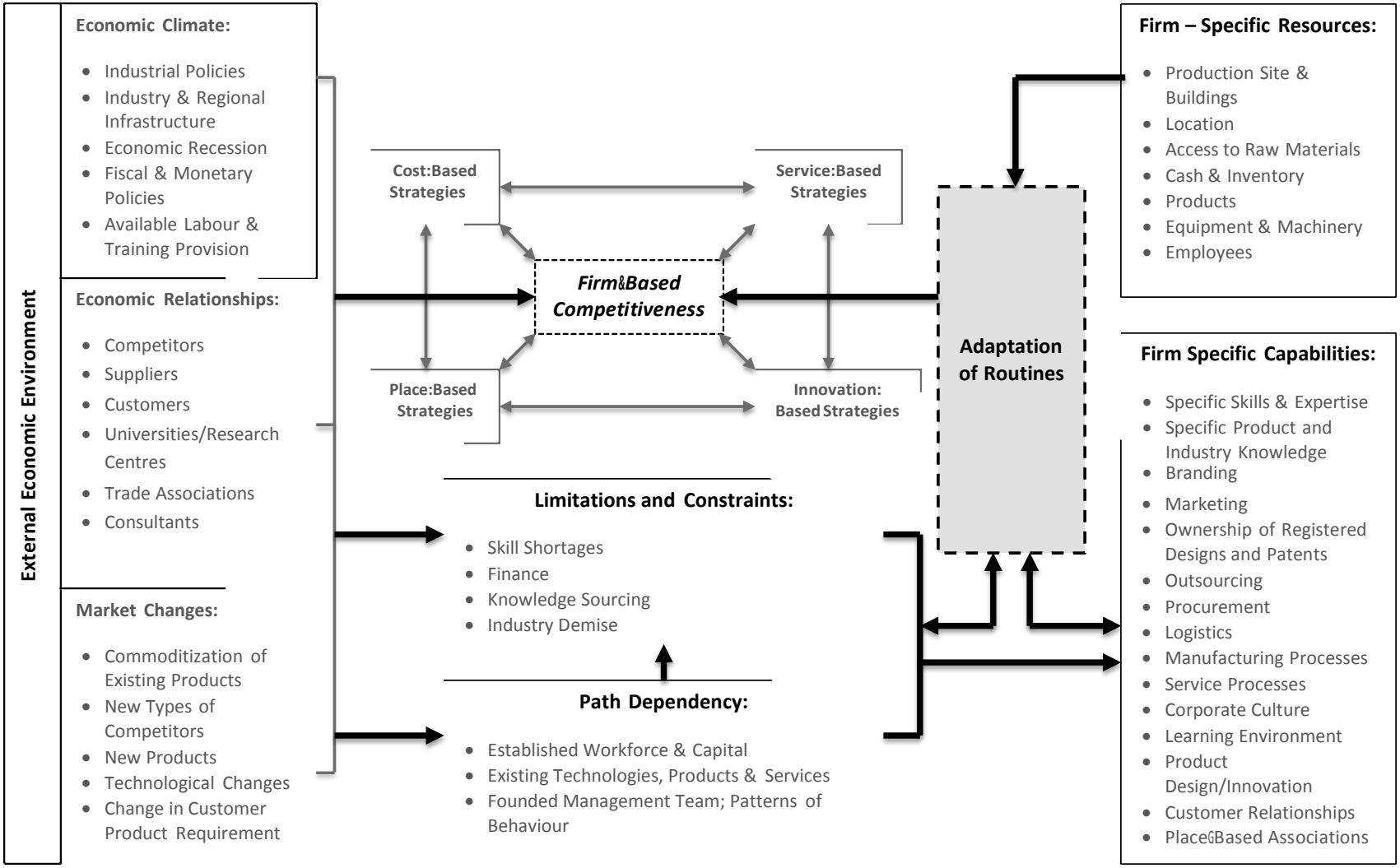
framework transforms these two perspectives. The E-RBV approach provides a focus on the examination of firm-specific resources within a capability and routine context. Organisational routines manage and organise firm-specific resources into firm-specific capabilities (Aldrich and Ruef, 2006; Nelson and Winter, 1982). Equally, firm-specific capabilities, path dependence factors, limitations to firm's capabilities (knowledge sourcing and skill shortages) and external environment constraints (industry demise and financial policies) determine the development and adaptation of routines (Section 2.5). The adaptation of routines informs the development of inimitable competitiveness strategies, which have to be implemented for firms to survive changes and pressures in their external economic environment (Chakravarthy, 1982; Martin, 2010; Martin and Sunley, 2010).

The E-RBV framework specifies the adaptation processes of firm's routines as an evolutionary process of firm-based competitiveness, in response to changes in their external economic environment (Figure 2.5). The framework advances the academic debates in the EEG and RBV literatures, as it highlights how a focus on routines (evolutionary approaches) must be combined with an understanding of resources and capabilities (the RBV of the firm) to theorise firm behaviour (Bryson and Ronayne, 2014). The theoretical integration of this framework contributes a micro-foundation for understanding the interdependencies between the firm and industrial dynamics, as well as the evolving economic geographies of manufacturing. The E-RBV framework provides a foundation to develop a practices firm-level empirical study, which contributes an understanding on firm-level behaviour and change, as well as firm-based competitiveness.

In particular, it contributes empirical evidence to the theoretical debates on the relationship between the development of new routines and firm's competitiveness (Aldrich and Ruef, 2006; Boschma and Frenken, 2006; Frenken and Boschma, 2007).

This thesis investigates the adaptation and evolution of UK TT manufacturing firms by studying each process of the E-RBV framework. The empirical chapters first identifies UK TT firm's resources, capabilities and path dependency characteristics, as well as investigate the current pressures and market changes in their external economic environments (Chapter 4) and then examines the competitiveness strategies developed in response to these changes (Chapter 5). UK TT firm's organisational routines are identified and the adaptation processes of specific routines to develop and implement firm's competitive strategies are discussed (Chapter 6). The limitations and constraints to firm's routines and capabilities, which challenge the sustainability of a firm's competitiveness, are then evaluated (Chapter 7). The next chapter discusses the research methods of this thesis, the crucial 'hinge' between the E-RBV conceptual framework and the empirical chapters (Barnes *et al.*, 2007).

Figure 2.5: E-RBV Framework: Competitiveness and Evolution of a Manufacturing Firm



2.7 Summary

During the twenty-first century a renaissance has occurred in political and academic debates regarding manufacturing firms located in developed market economies (Foresight, 2013). The review of this literature identifies the need for theoretically informed empirical studies, which develop an understanding on the adaptive characteristics and processes of firms to new technologies and markets, which has enabled them to maintain manufacturing systems in a high-cost location (Bryson and Taylor, 2010; Bryson *et al.*, 2008; Hudson, 2010). This thesis develops a novel firm-centred approach to understanding sources of firm-based competitiveness and the evolving economic geographies of manufacturing, by blending the RBV of the firm and EEG perspectives.

This chapter has reviewed the literatures on these two related theoretical perspectives to develop a new conceptual framework: the Evolutionary-Resource-Based View (E-RBV) framework. The E-RBV framework defines the firm as a site of organisational routines, which are developed and modified by the processes of blending firm-specific resources into distinctive capabilities (Table 2.3). It informs an understanding on the foundation of firm-based competitiveness as the development of inimitable strategies, which are informed by the adaptation of firm's routines to develop distinctive capabilities (Figure 2.5). The E-RBV framework is the theoretical foundation, upon which to base the analysis and discussion of this thesis. The next chapter provides a detailed discussion of the research methodology.

3 RESEARCH METHODS FOR STUDYING A UK MANUFACTURING SECTOR

3.1 Introduction

Building upon the previous chapter, which developed the E-RBV theoretical framework for this thesis, this chapter provides a detailed account of the research methodology that was developed to investigate the adaptation and evolution of UK TT manufacturing firms. Each process of the E-RBV framework will be explored to develop an understanding on the sources of firm-based competitiveness, as well as the adaptation of organisational routines to develop and implement inimitable competitive strategies (Chapter 2). The primary research design of this thesis is a comparative firm-level analysis of 40 UK TT firms with a response rate of 52.5 per cent. The analysis is firm-based rather than regional-based, but importantly a focus on a substantial representation of TT firms has informed an understanding on the industrial evolution, the restructuring and technological progress, of the UK textile industry to TT (Boschma and Martin, 2010; Hassink, 2010).

Qualitative approaches have been utilised to ensure methodology openness, which unveils the complexity and identifies the idiosyncratic behaviour and routines of firms (Bazeley, 2013; Boschma and Martin, 2007; Smith, 1987). Interviews were used as the main research

technique to obtain rich accounts of firm's daily practices and codes of behaviour (Aldrich and Ruef, 2006; Crang, 2002; Robinson, 1998; Valentine, 2005). Qualitative data analysis techniques were then employed for 'categorisation and connection' of the different accounts by the firms (Kitchin and Tate, 2000: 229). Alternative qualitative techniques of focus groups or participant observation would not have been appropriate for this study. It would have been difficult to conduct focus groups with firms, as the UK TT industry is a commercially sensitive sector related to its intellectual property rights (Longhurst, 2003; Saunders *et al.*, 2009). Identifying and accessing firms highlighted their concerns over confidentiality in sharing specific practices and competitive strategies with one another. Equally, the time frame of this study would not have permitted a comparative study of a sufficient number of firms, which would be representative of the sector, to be undertaken with participant observation (Bryman, 2008).

The following account outlines the research techniques of this study. A detailed account of the industry and firm sampling strategy is provided (Section 3.2), followed by a discussion of the data collection process, which includes ethical considerations and positionality of the researcher in relation to the research (Section 3.3). The data analysis process and techniques utilised is then outlined (Section 3.4). The validity and interpretation of this study is next examined (Section 3.5), highlighting that the analysis can be generalised across the UK TT industry and inform the analysis of other similar sectors, before a final summary of the chapter is provided (Section 3.6).

3.2 Industry and Firm Sampling Strategy

An initial challenge to this thesis has been to identify the UK TT sector, due to inconsistent universal definitions, as well as a lack of accurate and published sources on TT (Chapter 1). To identify a research sample, the researcher developed their own definition of TT, which foregrounds firms producing technical fabric rather than final assembly involving textiles. TT is high value-added textiles, which consist of technical properties through the addition of several and varied technical attributes (textile fibre, manufacturing and finishing processes) (Section 1.3). The UK TT industry contains firms with similar production characteristics and markets, as they manufacture intermediate TT fabric for convertors and fabricators to transform TT into complete products, for example wind turbines and aeroplane ejector seats (Bryson and Ronayne, 2014; Ronayne, 2015).

Sampling is the selection process that defines the unit of analysis, to capture the information needed to meet the research questions (Bryman, 2008). A purposive sampling framework was utilised to identify the UK TT industry, which met a specific criterion guided by the study's conceptual framework (Table 3.1). The UK TT industry had the highest association to the sampling criteria. This industry also met the textile research interests of the researcher, as her previous research has explored apparel manufacturers in Derbyshire and the UK Carpet Industry (Bryson and Ronayne, 2014).

Table 3.1: Industry Sampling Criteria

Industry Identification Criteria	Theoretical Justification for Criteria
1. An industry strategic and relatively active to the UK economy in terms of highest GVA & employment.	To ensure the firms studied are part of an industry that is growing and strategic to the UK economy.
2. An industry that has experienced intense international competition.	To understand firm-based competitiveness and strategies developed to maintain production in the UK.
3. A traditional industry that demonstrates evolution to a new industrial path.	To understand the adaptation and evolution processes of a firm.
4. An industry involved in emerging and innovative technologies.	To define and develop an understanding on high value manufacturing firms in the twenty-first century.

Source: Author (2011)

In the UK, there are two key outputs in the manufacture of textiles: textiles and wearing apparel. The TT industry is a micro-industry within textiles manufacturing (Appendix A). The selection of TT as the focus of study, instead of wearing apparel, involved three further stages in the sampling strategy. First, desk-based research of existing studies on the textiles industry in the social sciences literatures, which revealed that no research had been undertaken on TT industry, with the exception of Hassink's (2007; 2010) study (Chapter 1). Second, six textile trade associations were approached to develop a scoping report on the UK TT sector and advise which area of textiles (apparel or textiles) is of particular importance to the UK economy (Lindsay, 2005). The majority of the trade associations (5/6 participants) stated that TT is the most significant and appropriate segment of textiles to

study (Table 3.2). Their justifications for selecting TT included emphasis on how TT is the high value and the fastest growing segment of textiles, which requires further empirical research (Alliance, 2015; TSB, 2008).

Table 3.2: Trade Association Responses for Scoping Review on PhD Study

Organisation	Response
Lancashire Textile Manufacturers Association (LTMA)	*"TT are the next big thing"*
TechniTex Faraday Partnership	*"TT is the fastest growing sector and the only game in town. All innovation is under the banner of TT for example, developing integrated electronics into textiles. TT can survive in the UK, as it's high value and high performance"*
NWtexnet	*"TT is a growth area with R&D into producing lighter weight materials and composites for the transport centre. TT will provide solutions to societal and technological needs in the future"*
East Midlands Textiles Association Ltd (EMTEX)	*"Manufacturing in textiles is all high-end. Firms either supply knitted fabrics for high street fashion or have moved into TT. The face of textile manufacturing is now in TT"*
UK Fashion and Textiles Association (UKFT)	*"There are key statistics on the fashion industry from the London Fashion Week and there are interesting areas of the textile industry in both fashion and TT"*
UK Trade & Investment (UKTI) Textiles	*"TT is where the innovation is"*

Source: Author (Field Survey, December 2011)

Third, further desk-based research highlighted how TT exemplifies the evolution of firms, transforming themselves from manufacturers of traditional textiles into fabricators of TT (Hassink, 2010). The TT industry therefore meets the theoretical aim of this thesis, to understand the evolutionary approaches of a manufacturing sector in a high-cost location (Chapter 1). The manufacturing process of TT is also a more advanced and high value process than traditional fabrics (Alliance, 2015; Byrne, 2000). A study of the TT industry therefore contributes to understanding and advancing the debate on the evolving economic geographies of manufacturing firms located in the UK (Livesey, 2006, 2015).

3.2.1 Industrial Placement with NWtexnet

Inconsistent reporting, statistics and background information on the UK TT industry (Byrne, 2000; Parry, 1998), led to a decision to undertake a three-month industrial placement between April and June 2012 with NWtexnet. NWtexnet are a support body to the apparel, textiles and TT industries in the North West of England (NWtexnet, 2012). NWtexnet was selected for the placement, as it was anticipated this organisation would be able to provide the researcher with a thorough understanding on TT. Furthermore, its location in the North West of England is where the TT sector is predominately clustered, in the traditional textile regions of Greater Manchester and Lancashire (Alliance, 2015).

The placement was supported and funded by EREBUS (Engaging REsearch for BUSiness Transformation) capacity building cluster initiative, which aimed to enhance business

research by driving business transformation. The EREBUS partnership was co-funded by the ESRC (Economic & Social Research Council) and co-ordinated by the universities of Aston, Warwick and Birmingham (EREBUS, 2012). A placement report produced by the researcher outlines the background and main activities of this placement, as well as an evaluation of the outcomes and deliverables (Appendix B). The placement was evaluated as part of the ESRC's review of the EREBUS end-of-award report and managed by the EREBUS project management group.

NWtexnet has over 80 company members and predominately delivers support to those members by providing training solutions and advice on new and emerging technologies. The organisation is led by four directors, which each have their own technical background and over thirty years' experience of the industry (Appendix B). NWtexnet have a strong presence in the UK and Europe. They are a member of the UK Sector Skills Council and Euratex (the EU textile trade association), a partner of Textile 2020 (the European advanced textile materials cluster), and involved in a portfolio of five European research projects.

The placement involved assisting in various training, research and grant bid projects, meeting companies and textile trade associations, and interviewing academics that have a research interest in TT. The researcher participated in UK and European TT conferences and workshops, which enabled a network of contacts to be developed in the TT industry and community. The researcher attended NWtexnet Industrial Advisory Board (IAB) meetings,

which involved discussing current quarterly economic conditions, share best practice and articulate concerns and needs of the sector.

The placement provided access to NWtexnet membership database, further grey literatures and reports on the sector. The placement therefore provided an instrumental contribution to this thesis. It enabled the development of an understanding of the TT sector and identify firms (Harvey, 2010). Importantly, the placement facilitated the researcher to become an 'insider' and negotiate access into a 'tightly knit community' of the small and closed UK TT industry (Mohammad, 2001; Mullings, 1999; Sixsmith *et al.*, 2003). During the placement, a credibility platform was created for this research through placement reports and recommendations, which was communicated to NWtexnet members and across industry platforms; it is noteworthy that 32.5 per cent (13/40) of the firms participating in this study were NWtexnet members.

During the placement, a research diary recorded the researcher's experiences and interview data (Cloke *et al.*, 2000). This data has been used as an additional research resource; it informed the direction of this thesis, provided introductory material for a book chapter publication (Publication 2) and excerpts from the research diary is included in the empirical chapters. Two company visits during the placement provided an opportunity to pilot interview questions, this subsequently assisted in the development of the research design of this thesis (Bryman, 2008).

Throughout the placement, transferable skills utilised in the research process: communication, confidence, project management, marketing, communicating research to business audiences, influencing skills and client-relationship management were developed. A strong working relationship was maintained with the organisation and this also included employment as a project assistant between 2013 and 2014. NWtexnet has therefore continued to play a significant role in the research process; this is examined further in the following sections of this chapter.

3.2.2 Identification of UK Technical Textile Firms

To identify TT manufacturing firms, the sampling procedure employed a similar methodology utilised by David Rigby Associates (DRA), a consultancy firm that examined the North West TT cluster in 2001:

> *'In our study we included companies in our list if we thought they were TT companies and/or if they, in effect, defined themselves that way on their websites, by being in particular directories, by attending or exhibiting at a certain trade show for example'* (DRA, Email Exchange, 9.11.2012).

For this thesis, the sample of firms was generated from a triangulation of sources (FAME; websites; internet searches; trade association and public directories; grey literature; academics) consulted between November 2011 and June 2013, to identify and develop a database of UK TT manufacturing firms (Appendix C).

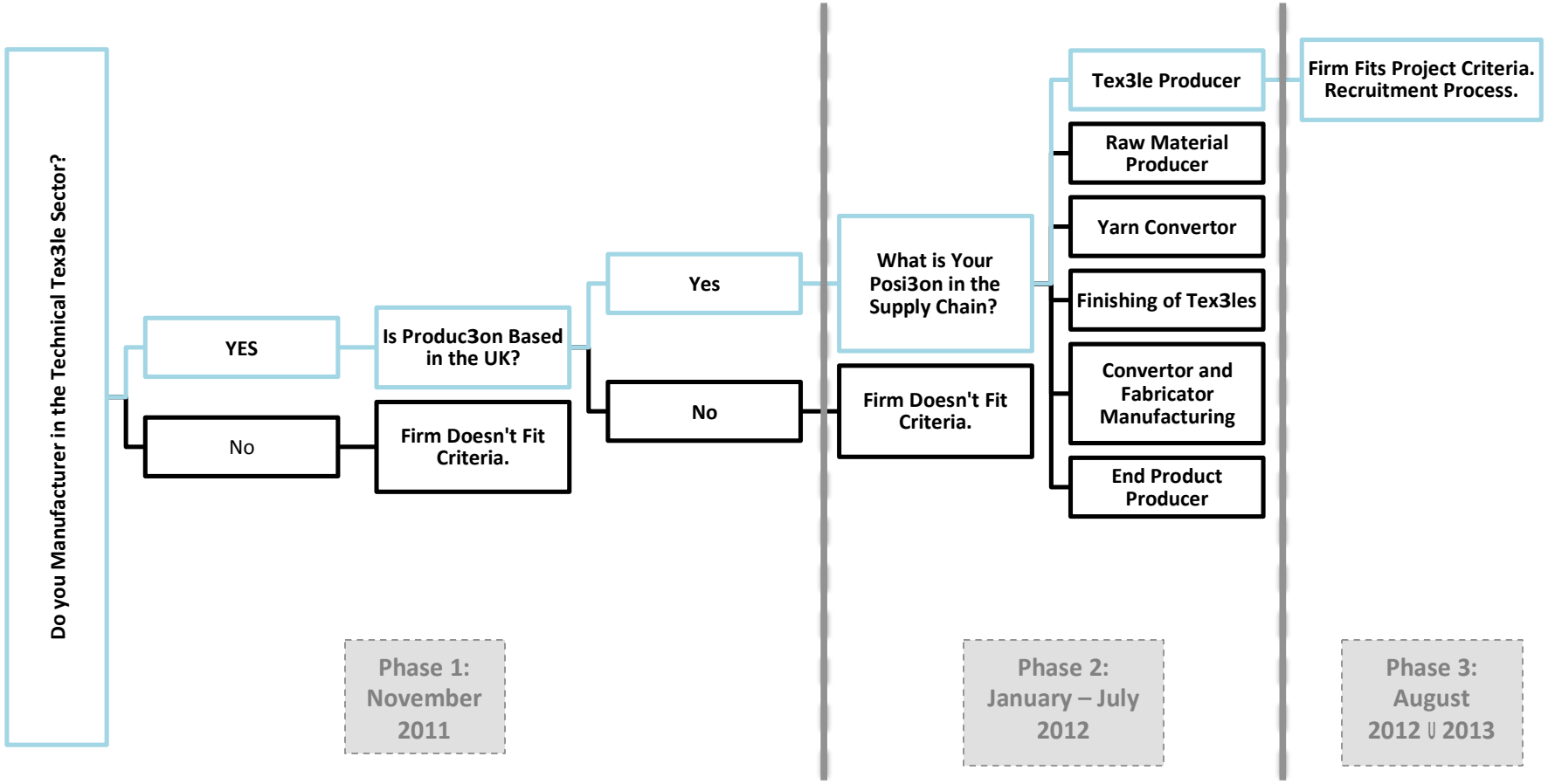
The business-oriented social networking site LinkedIn was utilised to identify firms (Papacharissi, 2009). Discussions were initiated in textile and manufacturing LinkedIn groups, which provides a platform for professionals in the same industry or with similar interests to share content, make business contacts and establish themselves as industry experts (LinkedIn, 2014). The discussions were entitled *'Calling all UK Technical Textile Manufacturers'* and posted a request for the researcher to connect with companies and industrial experts in the TT sector. This provided further information on the TT industry, as well as company names, providing a snowball sample (Denscombe, 2010).

Snowballing is an important technique for researching populations that are difficult to access (Atkinson and Flint, 2001). It is the process of using one participant to assist in identifying or recruiting another in the same selection criteria, who in turn can put the researcher in touch with someone else (Valentine, 2005). Further identification of firms through snowballing occurred during the data collection process (Section 3.3), as firms interviewed recommended further sources of directories, exhibition lists and trade associations to consult, as well as recommending firms that had not been identified from previous sources.

After identification and assembly of a company database on the UK TT industry, a data cleansing process was undertaken. First, each source was cross-examined to remove duplicate company names. Second, to confirm firms were actively trading, M&As, closures and multiple company names registered at the same postcode were checked through firm

websites, online searches and the FAME database. Third, a telephone survey was undertaken to all the firms in the final database to confirm their characteristics and to ensure they were TT firms (Figure 3.1). The telephone survey was time-consuming but provided instantaneous responses (Denscombe, 2010) to ensure firms manufactured TT fabric, rather than assembled products, and production was based in the UK. The sampling framework of this thesis has resulted in a sample of 76 TT firms as the unit of analysis, which are part of a relatively homogeneous group of the UK TT industry (Bryman, 2008; Denscombe, 2010; Parry, 1998). The next section examines the response rate and the process of negotiating access to this sample of firms and explores the interview process and related ethical considerations.

Figure 3.1 Technical Textile Firm Identification Telephone Survey (Field Work 2012 – 2013)



3.3 Data Collection Process

Data collection of this thesis began with desk-based research and telephone surveys to trade associations, firms and academics to develop an understanding on the UK TT sector at the beginning of the research process in November 2011. The study is based on in-depth qualitative interviews with 40 firms, which occurred over a thirteen-month period between September 2012 and October 2013. Additional data has been collected from a range of primary and secondary sources, which are incorporated into the analysis dataset. Further primary data collection includes eleven interviews with industrial experts, four interviews with academics (Table 3.3), and field notes taken at industrial events and conferences.[3] This provided a foundation for the researcher to develop an understanding of the UK TT industry: its history, emergence, current technological innovations and future developments.

Table 3.3: Data Sources

Data Source	Participants Interviewed
Technical Textile Firms	40
Industrial Experts	11
Academics	4
Total	**55**

Source: Author (2014)

[3] Industrial events attended included an IAB of NWtexnet (March, 2012); 2BFUNTEX meeting Croatia (June 2012), 2BFUNTEX meeting Brussels (March 2014), IoD event (June 2012); Nonwovens Network Meeting (July 2013); Conference at Brussels (March 2014); TT Conference at Bentley (April 2014).

Secondary data sources utilised include corporate brochures, company websites, industry magazines, websites and blogs. A research diary was kept throughout the data collection process to record data and the researcher's experiences, which was an effective channel for the inclusion of the researcher in wider reflections of the research (Cloke *et al.*, 2000). This additional data provides triangulation to the dataset of this thesis, enabling the researcher to maximise their understanding and verify, cross-reference and clarify any issues raised in the firm interviews (Kitchin and Tate, 2000; Kvale and Brinkmann, 2009; Longhurst, 2003). The next four sections discuss the data collection stages – the pilot study, access methods, interview process and the ethical considerations - of the qualitative interviews with the 40 UK TT firms.

3.3.1 Stage 1: Pilot Study

A pilot study was conducted in September 2012 with the first three UK TT firms interviewed, which have been incorporated into the analysis dataset: N-M-Weaver-1, 2012; E-M-Weaver-2, 2012; N-S-Knitter-1, 2012. The pilot study was positioned for the researcher and firms to have an open discussion that would compare the academic understanding of the study to the firm's perspective, identify the key issues for UK TT firms and examine the suitability of the methodology for this thesis. It highlighted the importance of desk-based research about each company before an interview (Moore, 2006), to develop a relevant conversation route of which questions were perhaps more relevant to one company and which areas of conversation would need probing further (Dunn, 2007). Significantly, this

exploratory study enabled the researcher to revise the research design, interview schedule and wording of the questions (Kitchin and Tate, 2000; May, 2011).

The pilot study asked firms *'are you innovating?'* and gained the response *'of course we innovate'* with information related to new product innovations. However, to meet the research enquiries of this thesis, interviewees needed to explain if their innovation capabilities influence the development of their competitiveness strategies, as well as discuss the role innovation plays in the different routines of the firm (Boschma and Frenken, 2006). A key adjustment to the interview schedule was therefore to include the use of the word 'change' rather than 'innovation', asking *'Please could you talk me through any recent changes in or to the company? Where and when have there been changes and why have there been these changes?'*

The pilot study led the researcher to reflect on 'why am I asking that question? What am I going to do with the answer? Will it have any implications for the company, my reputation as a researcher or for the field in general?' (Bryman, 2008). This reflection was initiated from the researcher attempting to gain detailed information on firm's customers, suppliers and financial and employee statistics in the pilot interview schedule. It became apparent from the pilot interviews that collection of this type of data would not be permissible by the firms due to the nature of the TT industry. Most of the firms producing intermediate products have confidentiality agreements in place with their suppliers and customers and

thus: *"a lot of things we do we can't talk about because we've signed Non-Disclosure Agreements (NDAs) to our customers"* (N-S-Knitter-1, 2012).

The UK TT industry is a small and closed industry with only 76 TT manufacturing firms, but plays an important role in providing intermediate products to other firms in a diverse range of industries. Firms were concerned with the researcher's access to commercially sensitive data and were reluctant to discuss client or supplier names in fear of 'giving away their customer address book'. Similarly, firms would not discuss profit and turnover or employee statistics in case of 'knowledge leakage', as they felt they would be identified by other firms in the industry from these datasets (Bryman, 2008; Saunders *et al.*, 2009). One firm agreed to participate in this study only once they had spoken to another firm, which had been interviewed about the interview questions. This firm stated they were willing to participate once they had identified from this other firm that *"*[the researcher had not] *asked for customer names, turnover, or for anything that could be construed as nosiness"* (E-M-[Narrow]Weaver-7, 2013). This emphasises the importance of reflection and negotiation in what type of data *needs* to be collected for a research study and striving for a balance between what is ethically desirable and practical, without compromising participants to gain a good story or 'crop of great quotes' (Bryman, 2008; Cloke *et al.*, 2000; Hoonaard, 2001; Reeves, 2010).

3.3.2 Stage 2: Access Methods and Response Rate

Accessing firms is both an art and a science (Goldstein, 2002): 'the science element concerns identifying firms and developing robust survey instruments while the art involves persuading individuals to participate in the study' (Hales *et al.*, 2013: 183). Access to UK TT firms was attempted between August 2012 and August 2013 through multiple methods (Table 3.4). A response rate of 52.6 per cent was achieved, with a total of 40 firms recruited out of the sample of 76 firms identified (Section 3.2.2).

Table 3.4: Methods of Access and Response Rate

Method of Access	Number in Sample	Number Successful	Response Rate (%)
Cold Called	76	2	5
Email	76	25	62.5
NWtexnet Introduction	5	4	10
Snowballing	6	5	12.5
Conference	1	1	2.5
LinkedIn	3	3	7.5
Total Firms	**76**	**40**	**52.6**

Source: Author (2014)

Emailing was the most successful method of access, recruiting 62.5 per cent (25/40) of the total study participants (Table 3.4). Email provides the opportunity 'to detail the purpose, nature and intent of research succinctly' (James, 2006: 298). Emails contained a covering letter with the participant information booklet attached (Appendix D). Negotiating access

to firms began with the phone survey that identified the sample (Figure 3.1) and a 'soft' selling strategy was utilised. Firms were informed of the background information on the researcher and study, and asked if they would be interested in being sent further information. This enabled the researcher to gain or confirm managing directors names and email details for 24 per cent (6/25) of the firms recruited via email.

The telephone survey occurred with secretaries or administrators, the gatekeepers of organisations, which 'have the power to grant or withheld access to people' (Burgess, 1984: 48). Gatekeepers try 'to protect the interests of their company and managers' (Harvey, 2010: 16), and as a result the majority of firm's details, in particular director's names (5/25) or email addresses (19/25), were not released to the researcher. For 20 per cent (5/25) of the firms, emails were sent to the firm's generic (sales or enquiries) email address. The 'mimicked email address' technique, which involves mimicking the email format of the firm – sales@textilecompany.co.uk --- to include the named individual --- joebloggs@textilecompany.co.uk --- was a successful method to bypass gatekeepers (James, 2006). This method provided direct access to directors and recruited 56 per cent (14/25) of the firms that were recruited via email. The emails were responded to instantaneously by 68 per cent (17/25) of the firms recruited. The remaining 32 per cent (8/25) of firms that had not responded to the first email, were followed up via a telephone call to be recruited, which was promised in the email (James, 2006; Longhurst, 2003; Ostrander, 1993).

The recruitment process was managed and recorded through a database to record which firms required the researcher to follow up and when. It was critical to persevere and some companies were repeatedly contacted over six months before a response was achieved, due to companies experiencing busy periods, holidays and taking time to consider the project (Harvey, 2010). The researcher was aware of achieving a balance between being persistent and being intrusive in following up emails and phone calls (Bryman, 2008). Nearly 20 per cent (15/76) of the sample did not respond after multiple contact attempts. The decision was then taken by the researcher in August 2013 to end any access attempts and to move the study forward to the next stages of analysis.

The timing of access is strongly associated to the success of recruiting participants. The researcher was aware of the temporal structures in the UK TT industry and planned access accordingly. Firms were likely to be busy towards the end of the tax year (5th April in the UK), in December and during the summer, as many small firms still close for a 'trades fortnight' (Hales *et al.*, 2013). In addition, the largest TT trade exhibition Techtextil that occurs every two years was in June 2013, which many firms were either visiting or preparing to exhibit at (Byrne, 2000). Flexibility of the researcher was critical for access, but this resulted in extending the time spent in the field (Ostrander, 1993). The researcher was also flexible in the geography of undertaking the interviews, with a UK wide study involving various return trips to the North West of England, as well as the researcher staying in Scotland for a set time period to access and interview firms when convenient for each firm (Harvey, 2010).

Other successful methods of access included the act of 'being there' and becoming an 'insider' to the sample community, specifically making social relationships and personal impressions (Mohammad, 2001; Sixsmith *et al.*, 2003). First, NWtexnet assisted in promoting the study to five members that they had a close working relationship with, which resulted in access to 10 per cent (4/40) of participants. Second, attendance at industry events such as conferences and workshops became an opportunistic access method. For each event, the researcher developed a rapport with the organisers beforehand to gain access to the delegate list. This would be cross-examined with the sample list to target firms at the conference for recruitment. One company the researcher had been attempting to recruit for a couple of months via telephone and email was successfully recruited at a conference once they had connected with the researcher in person. Third, the social media site LinkedIn enabled the researcher to directly connect with individuals affiliated to the organisation, which overcame access barriers of gatekeepers and undelivered or blocked emails. A strong profile and growing network signalled creditability to potential participants, increasing the 'attractiveness' for further individuals to connect to the researcher (Donath and Boyd, 2004; Papacharissi, 2009). Profile 'stats' notified the researcher which potential participants had viewed her profile to target further for recruitment (Van Dijck, 2013). Additionally, LinkedIn enables firms to 'anonymously' view the researchers' profile, this may have been the case after receiving a cold call or email to 'check the researcher out' and confirm their identity and led to indirect recruitment (Sixsmith *et al.*, 2003).

Negotiating access involves careful consideration of why participants would sacrifice their own time to be involved in research (Bryman, 2008). A 'sales pitch' to firms included promoting this study as an opportunity for them to offer their opinions and 'insider' knowledge, to discuss and reflect on the firm's activities, and the provision of a summary report on the conclusion of this project, which provides firms with insight into the strategies other firms have developed to remain competitive (England, 1994; Hales *et al.*, 2013). The researcher informed firms that this study was the first major piece of social science research on the TT industry. This was an inducement to participate as the sector suffers from inconsistent reporting and a lack of empirical research or interest (Byrne, 2000; Hassink, 2007). In addition, the researcher stated how this research was of direct relevance to the firms, as the research could be utilised to inform the political and educational agenda on manufacturing, with specific emphasis on the importance of manufacturing and the career opportunities for young people (Hales *et al.*, 2013).

Access to UK TT firms was difficult because of concerns over commercial sensitivity related to intellectual property rights (Saunders *et al.*, 2009). This thesis has ensured confidentiality of the information gathered through practiced research ethics and consent forms (Section 3.3.4). Nevertheless, access to UK TT firms still remained difficult, as firms are increasingly concerned about knowledge leakage or being identified from the study:

> *"The view is that it will likely take considerably more than 45 minutes to provide adequate answers to the questions which you have posed. The offer of the sectoral report at the conclusion is felt likely to be of limited utility to us, over that information which we already know about our sector and our competitors. Also, as*

> *we are a fairly large employer in this sector, then the feeling is that some of the anonymised data could be identified as being pertinent to our company"*
>
> (Email Exchange with Declined Respondent, 2013).

Another difficulty in gaining access to firms included firms perceiving a lack of benefit from participating in the project, firms stated they were becoming increasingly concerned *"with having interviews like this, because all* [they] *do is give away information and* [do] *not get any investment back"* (E-M-Weaver-10, 2013). The debate on the conduct and role of academic research in aiming for practical relevance to policy, society and business organisations (Martin, 2001), needs reigniting to guide junior researchers in corporate environments to achieve access and conduct good ethical research (Bryman and Bell, 2015; Hales *et al.*, 2013).

Representativeness of Sample

The final study sample includes 40 UK TT firms, which represents over half (52.6 per cent) of the population of 76 firms in the UK TT sector (Section 3.2.2). The representativeness of the sample to the wider UK TT industry is illustrated by region, production type, and size of firm in Table 3.5.

Table 3.5: UK TT Industry and Representation of Accessed Sample

Region	**Total**	**Accessed Firms**	**% Sample Representation**
Yorkshire & the Humber	9	5	55.6
West Midlands	5	2	40
Wales	1	1	100
South West	5	3	60
Scotland	7	5	71.4
Northern Ireland	1	1	100
North West	30	13	43.3
East Midlands	16	10	62.5
North East	1	0	0
South East	1	0	0
Production Type	**Total**	**Accessed Firms**	**% Sample Representation**
Weaving	39	24	61.5
Knitting	16	8	50
Nonwoven	18	7	38.9
Bobbinet	1	1	100
Braid	2	0	0
Size of Firm	**Total**	**Accessed Firms**	**% Sample Representation**
Small (up to 50 employees)	31	12	38.7
Medium (up to 250 employees)	37	26	70.3
Large (more than 250 employees)	8	2	25
Total	**76**	**40**	**52.6**

Source: Author (2014)

The sample geographically represents the UK TT sector, as over 40 per cent of firms are represented in each geographical region, with the exception of a firm in the North East and the South East of England. Importantly, the historic textile regions of the North West, East Midlands and Yorkshire are sufficiently represented (Alliance, 2015). This is required to meet the research questions of analysing the path dependence and evolution of firms (Martin and Sunley, 2006). The sample is representative of the different production types, with nearly 40 per cent of each type represented, with the exception of braiding. Significantly, the traditional and older production types of weaving and knitting are represented with over 50 per cent in each sample, which again is important for the aim of this thesis in understanding the adaptation of traditional textile processes to the new market and applications of TT (Boschma and Frenken, 2006; Hassink, 2007). The sample is slightly over represented in medium sized firms, which might be due to these firms having more resources available to participate. Medium sized firms have a slightly larger structure and available resources in comparison to small sized firms to provide the time to be involved in the study, especially when 'in smaller firms it is common to find that the managing director 'does everything' and comes 'off the line' to participate in the interview' (Hales *et al.*, 2013: 180). To summarise, the sample of 40 firms interviewed can be generalised to the TT firms in the UK sector, with no systematic and relevant differences between the firms that were interviewed and those that declined to participate (Bryman, 2008; Denscombe, 2010; Goldstein, 2002).

3.3.3 Stage 3: Firm Interviews

Interviews are 'a conversation with a purpose' (Berg, 2004: 75) and yield rich insights into the working practices and decision-making within firms (Dunn, 2007). Interviews were conducted with 40 UK TT firms between September 2012 and October 2013. The interviews were conducted in a semi-structured format. This enabled respondents to discuss points at length and raise issues not anticipated by the interviewer (Berg, 2004; Valentine, 2005). The interview schedule was informed by the E-RBV framework, past interview schedules and transcripts from previous related studies (Bryson and Ronayne, 2014; Ronayne, 2010), desk-based research and the placement with NWtexnet. The interview schedule identified firm's routines by asking interviewees to 'walk the interviewer' through the history and main products of the company, its organization, innovation and production processes from 'when an order is received to delivery', the development of competition strategies and the barriers to these strategies and routines. The schedule was formatted into six potential conversation topics evolving around: company background, production process, change, competition, risks and opportunities, and the TT industry (Appendix E). Each conversation topic contained sub-questions and prompts to guide and prepare the interviewer for potential discussion points, as well as retain flexibility (Berry, 2002; Healey and Rawlinson, 1993; Kvale and Brinkmann, 2009).

All interviews were recorded using a dictaphone to allow the researcher to engage in conversation with participants (Valentine, 2005). Reflection sheets were completed after each interview, which noted any key concepts and information, and also notes on the

interview process (Appendix F). The length of the interviews varied between 30 minutes and 3 hours (Appendix G). Face-to-face interviews were conducted with 82.5 per cent (33/40) of the firms and phone interviews with 17.5 per cent (7/40), where a suitable time could not be arranged with the respondents. The mode of the interview did not affect the data collected, as there are 'similarities in the quantity, nature and depth of responses' (Sturges and Hanrahan, 2004: 113).

The location of the interview produces 'micro geographies of spatial relations and meaning' (Elwood and Martin, 2000: 649). Face-to-face interviews occurred at firm's premises, as elites in the corporate interview prefer to be interviewed in their own territory (Hales *et al.*, 2013; Longhurst, 2003; Valentine, 2005). Further, face-to-face interviews presented the opportunity of a factory tour with 66 per cent (22/33) of firms. Not all of the firms could offer a factory tour due to NDA and confidentiality agreements in place with customers: *"so that's our secret area, which I can't show you, so that's where we do all the tapes and fabrics and… a lot of the R&D and samples of things"* (E-S-Nonwoven-6, 2013). The factory tours became a 'walking interview' facilitating 'mobile conversation', which was more relaxed and informal than in an office setting and enabled the researcher to observe and understand the economic environment discussed in the interview (Jones *et al.*, 2008). During the factory tours there was the additional opportunity for the researcher to engage in conversations with employees on the shop floor, which provided further insight on the firm. Factory tours were audio recorded, managed and analysed to the same method as the other interviews.

Table 3.6: Participant Occupational Role in Firm

Participant Interviewed		
Role in Company	**Number**	**Percentage**
President	1	2.2
Managing Director	23	50
Operations Director	9	19.6
Sales Director	6	13
Business Manager	4	8.7
Technical Director	3	6.5
Total	**46**	**100**

Source: Author (2014)

Managing directors were targeted for the interviews, because they are the most knowledgeable person to provide a complete overview on the background, recent changes and decision-making processes of the firm (Desmond, 2004; McDowell, 1998; Schoenberger, 1991). However, in larger firms it is much harder to gain access to the managing director compared to someone involved in operations or marketing (Hales *et al.*, 2013). Managing directors were accessed and interviewed in over half of the firms (Table 3.6), of which all of the firms were SMEs, with exception of one large sized firm. In 42.5 per cent (17/40) of firms, the managing director could not be interviewed either due to timing or delegation. Some managing directors delegated the interview to another director, who they stated would be more knowledgeable on the background and daily running of the firm, especially when the managing director was newly appointed to a firm. The interviews occurred with interviewees in a range of director and management roles (Table 3.6). At five of the firms,

the researcher was invited to interview an additional participant, the sales or technical director, which resulted in a total of 46 interviews.

The methodology attributes and characteristics of the 40 firms interviewed include the location of the interviews, ownership and whether the firm is a single site enterprise or part of a multi-site organisation (Appendix G). The sample consists of 18 firms with single site enterprises that are British owned and 22 firms with multiple site enterprises. Multiple site enterprises include firms that are a subsidiary production unit of a group corporation, 12 of the 22 firms are internationally owned. The 10 British owned multiple-site enterprises have additional production sites either in the UK or overseas near markets of USA and China or in low-cost production locations of Sri-Lanka and Poland. Single interviews with the 40 firms are the primary source of data for this thesis, and the site of where the interview took place represents the information collected on each firm. This is because it was the managing directors or a member of the management team of the UK production site that was interviewed and not the group managers of these multi-site organisations. Analysis focuses on the UK site interviewed as these sites act as autonomous business units with specific firm-level decision-making and routines (Aldrich and Ruef, 2006; Boschma and Frenken, 2011). Relevant interaction with other sites of a group is reflected in the analysis and made reference to when it influences the decision-making, routines or capabilities of the UK site.

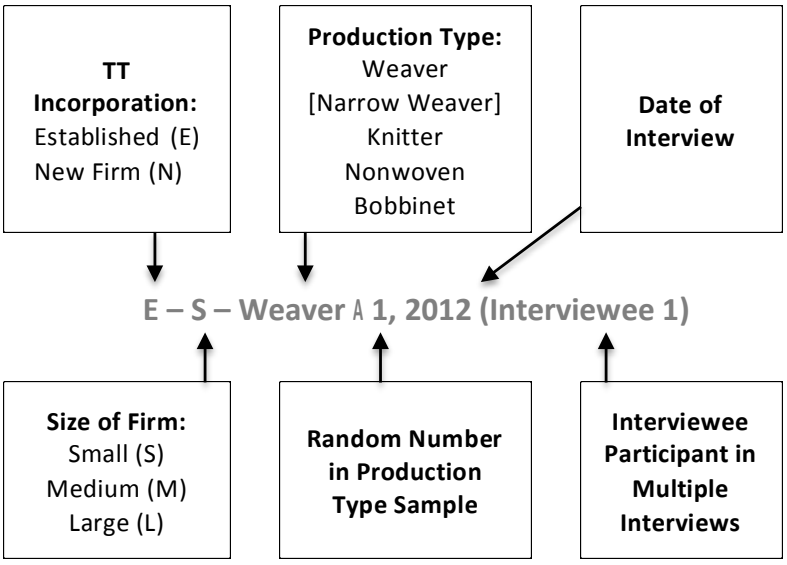
The interdependencies between firms at the micro-level and their external economic environment was captured by firm's interpretations of their economic relationships (E-RBV framework) and intermediary interviews with academic experts and trade associations (Table 3.3), which discussed the organisation of the TT industry and industry-support measures (Hassink, 2007). Desk-based research further provided an observation on firm's participation at trade events, their websites and social media interaction on LinkedIn and Twitter (Moore, 2006).

3.3.4 Ethical Considerations and Positionality

Good ethical conduct ensures high quality and integrity in research (Bryman, 2008; Punch, 1994; Truman, 2003). The University of Birmingham Ethical Review Committee approved a formal ethical review for this study (Van den Hoonaard, 2002). As a firm-centred study, the main ethical considerations were research transparency and confidentiality (Cloke *et al.*, 2000). Informed consent provided a formal solution to issues revolving around confidentiality (Guillemin and Gillam, 2004). First, informed consent provides prospective participants with sufficient information about the research to make an informed decision about whether or not they wish to participate (Bryman, 2008; ESRC, 2012). A participant information booklet (Appendix D) was provided and retained by each potential participant, which contained the necessary information for participants to gain a full understanding on the study (Bryman, 2008). Second, informed consent requires valid consent to be obtained from each participant. A consent form informed by the ESRC and the University of Birmingham guidelines was developed (Appendix D), which required the participant to

agree consent to the management and processing of data, audio recording of the interview and the confidentiality agreement of this study. Confidentiality of the firm, participants and data has been ensured through the use of pseudonyms in all transcripts and records. Each firm has been assigned a unique identification code (Figure 3.2).

Figure 3.2: Firm Identification Code



Source: Author (2014)

This code provides the reader with context on each firm as it details whether a firm is Established (E) or Newly Created (N), its size --- Small (S), Medium (M), or Large (L) – and its production type(s) (Knitter, Weaver, Narrow Weaver, Bobbinet or Nonwoven). The firms are grouped by their production category and a randomised number is assigned to multiple firms in this category. For example, in the weaving category there are twelve firms so each firm has been assigned a randomized number between 1 and 12, using an online random

number generator, to ensure firms are not in numerical order to the interview order (Random, 2013). The date of the interview is then provided. If there are multiple participants in a single firm interview, they are represented by assigning an additional label of 'Interviewee 1' or 'Interviewee 2' to the code.

Positionality

Positionality, defined as 'how we are positioned (by ourselves, by others, by particular discourses) in relation to multiple, relational social practices of difference (gender, class, race, ethnicity, age, sexuality and so on), which also means we are differently positioned in hierarchies of power and privilege' (England, 2006: 289). In this study, the positionality attributes of the researcher included being female, in her early twenties, with a British northern accent, occupying a student status and an affiliation to the TT industry. The research context of this study is the manufacturing sector. The characteristics of the manufacturing sector pose specific challenges for access to participants and interviewing, as Hales *et al.* (2013: 180) describes:

> 'The sector is characterised by varying organisational forms such as old family businesses, micro enterprises and large multinational companies with elites holding different roles in individual firms. In smaller firms, it is common to find that the managing director 'does everything' and comes 'off the line' to participate in the interview. The setting of the business, often noisy, lacking a clear entrance and with the majority of employees being male, offers additional considerations for the fieldwork process and particularly accessibility'.

The manufacturing environment involves the researcher undertaking corporate interviews, where they are attempting to access and interview an elite. Elites are defined as a person exercising the major share of authority or control (Herod, 1993; Parry, 1998). Elite interviewees may be in the position of power as holders of specialised knowledge (Harvey, 2010; Smith, 2006). This transforms researchers into 'supplicants' who have to be grateful for an elite's co-operation (Welch *et al.*, 2002). Corporate interviews are therefore critiqued for lacking texture (Crang and Malbon, 1996) and for only providing a situated interpretation of events driven by power inequalities and corporate cultures (Hales *et al.*, 2013; Hughes, 1999). However, reflexivity on a researcher's positionality can enable a researcher to be aware of how to negotiate power relations and shape the research process positively to collect reliable data (Crang, 2002; Herod, 1993).

The researcher adopted the strategy of 'stretching the elasticity of positionality', which involved adapting the researcher's positionality to the context and setting, and manipulating the gap between the researcher and interviewee to negotiate any unequal power relations (Hopkins, 2009; Nast, 1994; Rice, 2010). In this study, 46 interviews were conducted at 40 manufacturing firms, and 91 per cent (42/46) of participants were male. In this male dominated environment, access may have been permitted to the researcher as a female, because women are perceived as 'warmer', less threatening than men and more intriguing (Cochrane, 1998; Gurney, 1991; Schoenberger, 1992). However, in the interview process, a women may be perceived to lack professionalism or creditability (Gurney, 1991; Reeves, 2010). Equally, the student status of the researcher may have been problematic for

gaining access due to a lack of reputation and title (James, 2006; Sixsmith *et al.*, 2003). For the interviews, the researcher consciously decided to wear the same professional outfit, a grey knee-length workwear dress, a black long-sleeved cardigan, black opaque tights and black court shoes. This was to control the variable (gender) and to balance any power relations in a corporate setting, as a woman can draw attention to herself by what she chooses to wear, particularly when working or researching in a masculine environment such as manufacturing (Hales *et al.*, 2013; McDowell, 1997). Strength of personality and character can also influence and persuade participants to first be involved in the study, as well as enable the researcher to gain access to specific data during the interview that the participant may not have anticipated disclosing before the interview was conducted (Berry, 2002; Reeves, 2010).

In addition, the researcher may have gained respect and credibility (Ostrander, 1993) through their NWtexnet placement, which provided the researcher with some affiliation to the TT industry (Harvey, 2010). The placement enabled the researcher to build a 'platform of credibility' through the experienced gained in participating in various projects, contribution to reports, workshops and conferences and connections made with key actors in the TT sector. The placement may have signalled to potential participants the researcher's knowledge and expertise developed about the industry, which may have impressed these elites as they 'checked the researcher out' (Sixsmith *et al.*, 2003: 581-586). However, the placement with NWtexnet may have also been a negative influence to the research process, which prevented the researcher from first gaining access to firms as only

13 out of a possible 25 NWtexnet members were recruited, and second influenced the type of data collected. The researcher's placement with NWtexnet occurred within the first year of the PhD and before access to UK TT firms was attempted, a public association and attachment to NWtexnet developed during the placement may have caused the researcher and this study to be perceived as not independent (Reeves, 2010; Sixsmith *et al.*, 2003).

To ensure reliability of the data collection process (Crang, 2002), the interviewer approached issues raised within and between firms 'from a number of different angles to check the consistency of responses' (McDowell, 1998: 2138). The research data was also analysed using rigorous and reflexive processes (Bazeley and Jackson, 2013; May, 2011). The next section outlines the analysis techniques undertaken on the data and information collected.

3.4 Data Analysis Process

Data analysis determines the quality, validity and reliability of findings (Flowerdew and Martin, 2005). The data analysis employed a grounded theory approach, using analytic induction of weaving back and forth between the data and theory to identify and generate themes and concepts from the research, which challenge and advance the E-RBV framework (Bazeley, 2013; Bryman, 2008). This approach, as Corbin (2009: 41) observes, was 'relaxed, flexible and driven by insights gained through interaction with data rather than being structured and based on procedures'. Identification of meaningful themes in the

data focused on what was stated within the text, with reference and reflection back to the research questions and E-RBV framework of this thesis, and was organised to build conceptual understanding and theory (Bazeley and Jackson, 2013; Bryman, 2008).

The software programme NVivo supported the data analysis process of all data collected (both primary and secondary) and ideas generated in the research journal (Bazeley and Jackson, 2013; May, 2011). Any work undertaken by hand (field notes, data capture forms) was entered into NVivo and created as a memo. Memos are linked to particular sources and can be coded, searched and queried to locate the researchers thoughts on a topic, by NVivo finding what was written about on that particular topic (Bazeley and Jackson, 2013). NVivo has been criticised for fragmentation of textual materials, removing the context of the data and disengaging the researcher from the data (Bryman, 2008; Hinchliffe *et al.*, 1997). Continuous reflexivity in the analytical process by the researcher married to the technological developments of the software, has enabled the use of computer aided qualitative analysis to become acceptable (Bryman, 2008; Kitchin and Tate, 2000). Furthermore, there are a number of benefits and advantages in using NVivo to assist the researcher in data analysis, which has led to an overall rigorous, high quality analysis and robust results (Bazeley and Jackson, 2013).

First, NVivo enabled the researcher to manage data efficiently in comparison to dealing with 'mountains of paper' of disparate materials, by linking a collection of sources (field notes, transcripts, newspaper articles, corporate brochures, websites, videos, literature) to

specific cases (firms) (Bazeley, 2007; Hinchliffe *et al.*, 1997). Second, the data could be retrieved instantaneously and systematically, which reduced time dedicated to data management, providing more time 'to think more clearly and deeply about the materials' (Crang *et al.*, 1997: 784). Third, the software provided a key advantage in the coding process by enabling the researcher to retrieve 'lists of codes, search for keywords and phrases, and view them in context' (Bird, 2005: 237), as well as expand, refine and revise coding themes instantaneously (Bazeley and Jackson, 2013), in comparison to coding by hand which 'can be messy, confusing and time-consuming' (Kitchin and Tate, 2000: 257). Rapid access to the original data source of a particular segment being studied, provides a counterargument to the criticism of the researcher becoming disconnected to the data using NVivo (Bazeley, 2007). Fourth, NVivo encouraged a slower, more reflexive and thorough data analysis as the researcher carefully read through the materials 'with a systematic tooth comb' (Hinchliffe *et al.*, 1997: 1117). Final advantages included the ability for the researcher to query the data by grouping, comparing and contrasting data, visually model data relationships and generate reports including statistical summaries (Bazeley and Jackson, 2013; Kitchin and Tate, 2000: 257).

The data analysis process was managed and recorded in a research journal as a memo. This audit trail enabled the researcher to document how they moved from initial exploratory ideas to the conclusions reached in this study (Bazeley, 2007; Hinchliffe *et al.*, 1997). Analysis began early during the data collection process with the NWtexnet placement through desk-based research and interview reflection sheets. These examined how the

data collected from each interview was contributing to the shaping of the research outcome results and identified any issues requiring further investigation (Appendix F). Thematic analysis, the development of themes, occurred early in the research process from these sources (Bazeley, 2013). This provided a useful starting point in developing a report of initial findings. Observation of a theme and any relationships across the data was recorded in 'analytic memos', which included descriptive writing about particular concepts and supportive explanations of what prompted the awareness of a theme (Bazeley, 2013; Bazeley and Jackson, 2013). An initial analytical model of these main themes was developed in NVivo, which provided a 'conceptual map' of observed associations and theoretical links (Bazeley and Jackson, 2013).

All the interview data was transcribed by the researcher, as this facilitated the close attention, familiarisation, interpretative thinking, and exploration of the data (Bird, 2005). Memos were created on each case (firm or industrial expert) to record theoretical and methodological issues and reflections that arose during transcription (Bazeley, 2007; Bryman, 2008). A second reflection on firm interviews occurred during transcription, which re-examined and challenged the original thoughts and ideas in the post-interview data capture forms (Appendix F).

The next stage of the analysis was the process of coding, 'tagging' a passage of data with labels or 'codes', that are constructed references based on the researcher's understanding of what that passage is about and relevance to the research (Bazeley, 2013; Cope, 2003;

Jackson, 2001). Coding stimulates and facilitates analysis, 'it provides a means of access to evidence; it is a tool for querying data, for testing assumptions and conclusions' (Bazeley, 2013: 125). In NVivo, coding is stored in 'nodes'. A node is created for each concept and contains the references to the exact location of the text, which has been coded in each source document. The software can then retrieve all the coded passages from the document records for subsequent analysis (Bazeley and Jackson, 2013).

There are two major stages of coding: initial and focused. First, initial coding began with reading through each transcript and assigning a list of free nodes to passages of text, which revolved around broad topics to develop an initial idea of themes emerging from the data (Bazeley and Jackson, 2013; May, 2011). It also included gaining attribute values of each case, for example employee numbers (Kitchin and Tate, 2000). Second, focused coding involved close re-examination of all interview transcripts to apply further nodes and categorise the data by generating clusters of child nodes within 'tree nodes', this sorted the data in categories of similar or related phenomena (Bazeley and Jackson, 2013). The relevance of each node was challenged and some nodes were 'parked', which contained interesting data, but was either irrelevant to the main research questions or a low number of sources were coded to it. For example, the node 'corporate social responsibility', originally a child node of the tree node 'competitiveness' has been 'parked', as only one source had been coded at this node. Nodes were continually revised, merged, and rearranged until a clear analytical coding structure was formed, illustrating the interrelationships between the concepts, and resulting in a 'codebook' that could answer

the research questions of this study (Appendix H) (Bazeley and Jackson, 2013; Bryman, 2008).

The analysis and results of this study were developed by querying the data and cross-case comparison, which identified connections and relations between ideas and elicited key interview quotes to support findings (Bazeley, 2013; Kitchin and Tate, 2000). A matrix of themes, major findings, processes and events was generated to look for patterns within and across the firms (Gillham, 2005). This matrix enabled quantitative data to be produced by observation of the number of firms classified at the same node or query, which supports the qualitative data of firm's interview quotes (Bird, 2005). Regular analysis reports were produced that discussed preliminary findings and provided a foundation for the empirical chapters. The next section examines the validity and interpretations of the results.

3.5 Validity and Interpretation of Results

The research process is 'complex, messy and serendipitous' in nature and shaped by 'luck, chance, intuition and opportunism' (James, 2006: 303). It is therefore important to be reflexive of the methodology of this study by utilising an evaluative criterion of credibility, trustworthiness, dependability, confirmability and transferability (Baxter and Eyles, 1997; Bazeley, 2013; Lincoln and Guba, 1985). Two significant methodological limitations exist in this study: the identification and sample of TT firms and the single interview (Bryman, 2008;

May, 2011). This section critically assesses these limitations and the strategies to ensure the validity and credibility of the conclusions of this study.

The UK TT industry is an emerging, elusive and un-researched sector and was 'hidden' from the social sciences literature and largely hidden from policy to identify and access (Byrne, 2000; James, 2006; Parry, 1998). The identification process of the UK TT sector has been outlined in Section 3.2. A purposive sampling framework was utilised, rather than generating a random sample, to ensure the sector and firms identified were of relevance to the research questions (Bryman, 2008). This enabled the researcher to access and collect data from a relatively homogeneous sample of firms producing TT fabric (Parry, 1998). However, in identifying the sector, the use of the term 'technical textiles' may have created a coverage error, meaning the research population identified of 76 TT manufacturing firms may not be comprehensive or fully representative of UK TT firms (Bryman, 2008). Human error could have missed companies in the identification search, sources utilised could have been inaccurate or out-dated and are dependent on whether firms include themselves in public directories (Hales *et al.*, 2013). Significantly, not all firms identify themselves with TT as firms claim it to be *"a very woolly area"* (N-S-Knitter-1, 2012) due to a lack of clarity and understanding of the term. Firms argued they are more likely to identify themselves with their markets than the TT industry: *"we see ourselves as part of the composite industry almost more than we see ourselves as part of the textiles industry"* (N-M-Weaver-1, 2012). The TT sector crosses over with many other industries and firms could be categorised in public sources to their markets, for example composites (DRA, 2001). The researcher

undertook the following measures to minimise the coverage error. The list of UK TT firms developed was checked with the firms interviewed, trade associations and academics related to TT and cross-examined with as many sources the researcher could detect and obtain (Appendix C). All 76 firms in the research population identified are therefore the main firms of the UK TT sector, as they repeatedly appeared on published sources and were recommended by industrial experts.

The second methodological limitation of this study was the use of the single interview. The single interview is criticised for lacking texture (Crang and Malbon, 1996), superficially thin in content (James, 2006; Martin, 2001), contaminated with 'corporate spiel' (Hales *et al.*, 2013) and only providing a situated interpretation of events (Dunn, 2007; Hughes, 1999). As the first study on TT, it was both extensive to understand the UK TT industry and intensive to understand UK TT firms. The study undertook interviews with 40 firms at only a single point in time. This was due to the nature of the study being based around multiple firm-based interviews, as well as constraints of time and budget that only made it feasible to conduct in-depth interviews once (James, 2006). Interviews with firms were very time-consuming: the interview lasted for an average of 90 minutes in length (Appendix G), travel to and from the firms that were located across the UK could take a day (2 days if an overnight stay was required), transcription of the interview took 2 hours for every 30 minutes conducted (1-2 days for each firm), and then an indefinable length of time was dedicated to detailed analysis of each transcript. The time parameters of this study would

therefore not allow for further interviews and raises the breadth vs. depth argument (Berry, 2002).

Several strategies were developed to minimise bias from the use of single interviews. First, in-depth and active interviewing was undertaken where 'meaning is not merely elicited by apt questioning, nor simply transported through respondent replies; it is actively and communicatively assembled in the interview encounter' (Holstein and Gubrium, 2004: 114). To facilitate the rigour and success of the interviews, the researcher developed a background understanding on each firm through triangulation of other sources (industrial placement), and communicated clearly to participants the information the interviewer intended to gather (Kitchin and Tate, 2000; Schoenberger, 1991; Valentine, 2005). The researcher assessed the interview continuously, picking up on any interesting topics to probe and delve deeper and raised any inconsistencies in responses (Berry, 2002; Harvey, 2010) The interview also involved a walk around the premises to gain a further understanding on the operation of the organisation. Furthermore, the interviews were conducted with the most knowledgeable person on the subject, predominately the 'corporate historian', which James (2006: 299) defines as 'an employee who has been with the company at least 10 years, or from start-up in the case of younger firms'. Based on their understanding of the firm, these key individuals provided a longitudinal profile of firms: establishment, history, changes in management, ownership and structure of industry (James, 2006), which met the evolutionary approach and research questions of this study (Boschma and Frenken, 2006; Boschma and Martin, 2007).

Second, reliability of data was achieved by triangulation and comparative checks on multiple data sources outlined earlier in this chapter for data accuracy and enrichment (Harrigan, 1983). Third, the researcher was reflexive throughout the research process by comparing results and posing verification questions across the multiple-cases of firms (Bazeley, 2013; Harvey, 2010). Regular analysis reports generated predictions and initial results to test against further data, and the audit trail provided continuous awareness of how pre-existing knowledge and ideas may be influencing the researcher's interpretation and understanding of results (Bazeley, 2013; Bryman, 2008). Fourth, some of the analysis and conclusions of this study have been published as a paper and a chapter in a high quality and peer-reviewed journal and edited book (Publication 1 and 2). This has provided consensual validation of the conclusions and interpretations of this research, as the acceptance of the findings as part of collective knowledge by a community of scholars suggests quality and value (Bazeley, 2013). Fifth, the presentation of firm's quotations in the empirical chapters has replicated James' (2006: 301) approach of using 'as many quotations from as many participants as possible' rather than 'cherry picking' quotes. The empirical chapters pitch quotes against each other when needed to highlight any complexities and contradictions in the data. In addition, the identification codes of each firm (Figure 3.2) describe their positionality (size, production type, age) for the reader to 'draw their own conclusions regarding the possible biases and allegiances shaping a respondent's testimony, and hence the quality and meaning of the quotations used' (James, 2006: 301).

Member checking, the checking of data interpretations made by the researcher with the participants of the study, is often regarded as a key strategy to ensure quality and plausibility of results (Bazeley, 2013; Bryman, 2008; James, 2006). However, the researcher decided not to employ this strategy due to the nature of the TT industry being highly commercially sensitive in relation to the intellectual property of product developments and knowledge leakage to competitors. As it had been a daunting and challenging task to gain access, as well as firm's trust and cooperation for interviews, the researcher believed if firms 'had a chance to review what they have said they may well decide that the material is too sensitive for publication and feel compelled to ask [the researcher] to withdraw it' (Parry, 1998: 2159). This became the case with the fourth firm interviewed, which reviewed the original interview transcript (20,000 words) and then requested that it be deleted and for a new interview to be conducted. This second interview provided a more 'corporate' view, containing 'public' information on the firm. Therefore, it was feared that to pass on any further transcripts to firms would have resulted in a synthetic, less real and raw data set on the industry. It would not have been viable to conduct the research in this manner, conducting numerous and repeated visits to firms, as well as transcription of interviews, due to the limited time and resources available in this study (James, 2006).

The sample of 40 firms is representative of the UK TT sector (52.6 per cent) and bias has been avoided by a good representation in terms of the geography, size and production type of firms. The researcher developed a significant knowledge base of the UK TT sector and connections in the industry from her industrial placement, which provided an advantage of

knowing about the characteristics of non-respondents (Goldstein, 2002). This enables the researcher to confirm the sample as robust, with no relevant differences between the firms that were interviewed and those that declined (Bryman, 2008). The sample size is small but relatively homogeneous and therefore variation between firms is reduced (Bryman, 2008). A quantitative analysis of the industry is not provided from this study, but sufficient information and data was collected and analysed from the qualitative approaches utilised to present a reliable case on the first study of UK TT firms (Schamp, 2005). The sample can be generalised to TT firms in the UK sector and inform the analysis of other similar sectors (Denscombe, 2010).

3.6 Summary

This chapter has provided a detailed account of the research methodology of this thesis and examined how the evidence base for the analysis has been developed. Comprehensive desk-based analysis of the UK TT industry identified a sector, which consists of 76 manufacturers producing technical fabric, than final assembly involving textiles. The primary research design of this thesis is a comparative firm-level analysis of 40 UK based firms, a response rate of 52.6 per cent. Access to these firms was difficult because of concerns over commercial sensitivity related to intellectual property rights (Saunders *et al.*, 2009). The sample in this thesis is representative of TT firms in the sector, with no difference between the firms that were interviewed and those that declined to participate.

The methodology utilises qualitative approaches and is based on detailed face-to-face interviews. Semi-structured interviews were undertaken between September 2012 and October 2013, and supplemented by data obtained from a placement with the TT trade body, NWtexnet, between April and June 2012. Additional primary data sources that was collected and incorporated into the analysis dataset, included intermediary interviews with industrial experts and academics, field notes taken at industrial events and the researcher's research diary. Secondary data sources include corporate brochures and websites. The interviews were transcribed and, to maintain anonymity, each company has been assigned an individual identification code. The data was analysed using qualitative techniques for 'categorisation and connection' (Kitchin and Tate, 2000: 229), and assisted by the software programme, NVivo, to manage the data collected and ideas generated for a rigorous and reflexive process (Bazeley and Jackson, 2013; May, 2011).

The findings from the data analysis process are presented in the subsequent four empirical chapters (chapters four, five, six and seven). The results begin in the following chapter with an overview of the key characteristics of the UK TT industry and an investigation into the adaptation processes of firms to enter into the production of TT. Chapter four provides the foundation for the subsequent empirical discussions.

4 MANUFACTURING TECHNICAL TEXTILES: UK INDUSTRY, ADAPTATION AND EVOLUTION

4.1 Introduction

This thesis is the first academic study on the UK TT industry (Section 1.4). Previous chapters emphasise how TT is a difficult industry to define and document (Byrne, 2000), however, a systematic and thorough research methodology has managed to identify the elusive UK TT industry (Chapter 3). The data collected informs an understanding on the type of firms in the industry and how these firms became producers of TT, high value-added textiles that consist of functional properties through the addition of technical attributes (Section 1.3). This chapter identifies the key characteristics of UK TT firms and the adaptation processes of firms to enter into the manufacturing of TT (Research Objective 1). During the second half of the twentieth century, UK TT firm's engaged in adaptation processes of learning and innovation to reallocate their resources and capabilities into new technological developments in textiles (Chakravarthy, 1982; Hassink, 2010; Martin and Sunley, 2006). This was in response to changes in traditional textile competitive dynamics, which revolved around a strong increase in competition from developing market economies (Martin, 2010). Adaptation to TT by these firms has resulted in industrial evolution, a renewal and restructuring, of the UK textile industry (Boschma and Martin, 2010).

In this chapter an industry analysis is undertaken to first outline the key attributes of UK TT firms (Section 4.2). The historical emergence and development of the UK TT industry in the twentieth century is next examined. This includes an investigation into the type of firms that diversified to TT (Section 4.3), the role of the UK government and industrial trade bodies in the formation of a UK TT industry (Section 4.4), and the different adaptation processes of firms, which enabled them to enter into the manufacture of TT (Section 4.5). The chapter the returns to the twenty-first century to examine UK TT firm's external economic environment (E-RBV framework). In particular, firm's competitors are identified with an investigation into key market changes of the commoditization of existing TT products and new types of competitors (Section 4.6). This is because 'the role of competition is especially formative' in promoting industrial evolution; 'the constant pressure of competition shapes the selection processes that determine the success and survival of firms and drive innovation and hence the production of variety' (Martin, 2010: 22). The chapter concludes by examining the E-RBV framework developed in Chapter 2 in context to the UK TT industry. It evaluates how this chapter confirms, contradicts or modifies the original framework (Section 4.7).

4.2 The UK Technical Textile Industry

The TT industry is a complex and heterogeneous sector with a diverse number of actors (Figure 4.1). The supply chain stretches from the manufacturers of polymers for technical fibres, weavers, knitters and constructors of nonwoven fabric, through to convertors and fabricators who incorporate TT into finished products (Byrne, 2000; DRA, 2001). In the UK,

it is the textile producers maintaining TT manufacturing systems and adding value through key innovations in TT products (Highlighted in Figure 4.1). UK TT firms are primarily small (less than 50 employees) to medium sized enterprises (less than 250 employees) (SMEs), with an average of ninety-seven employees (Table 4.1).

Table 4.1: Employee Size of Technical Textile Firms

Size of Firm	Frequency of Firms	Percentage (%)
Small (Up to 50 Employees)	12	30
Medium (Up to 250 Employees	26	65
Large (More than 250 Employees)	2	5
Total	**40**	**100**

Source: Interview Data 2012-2013.

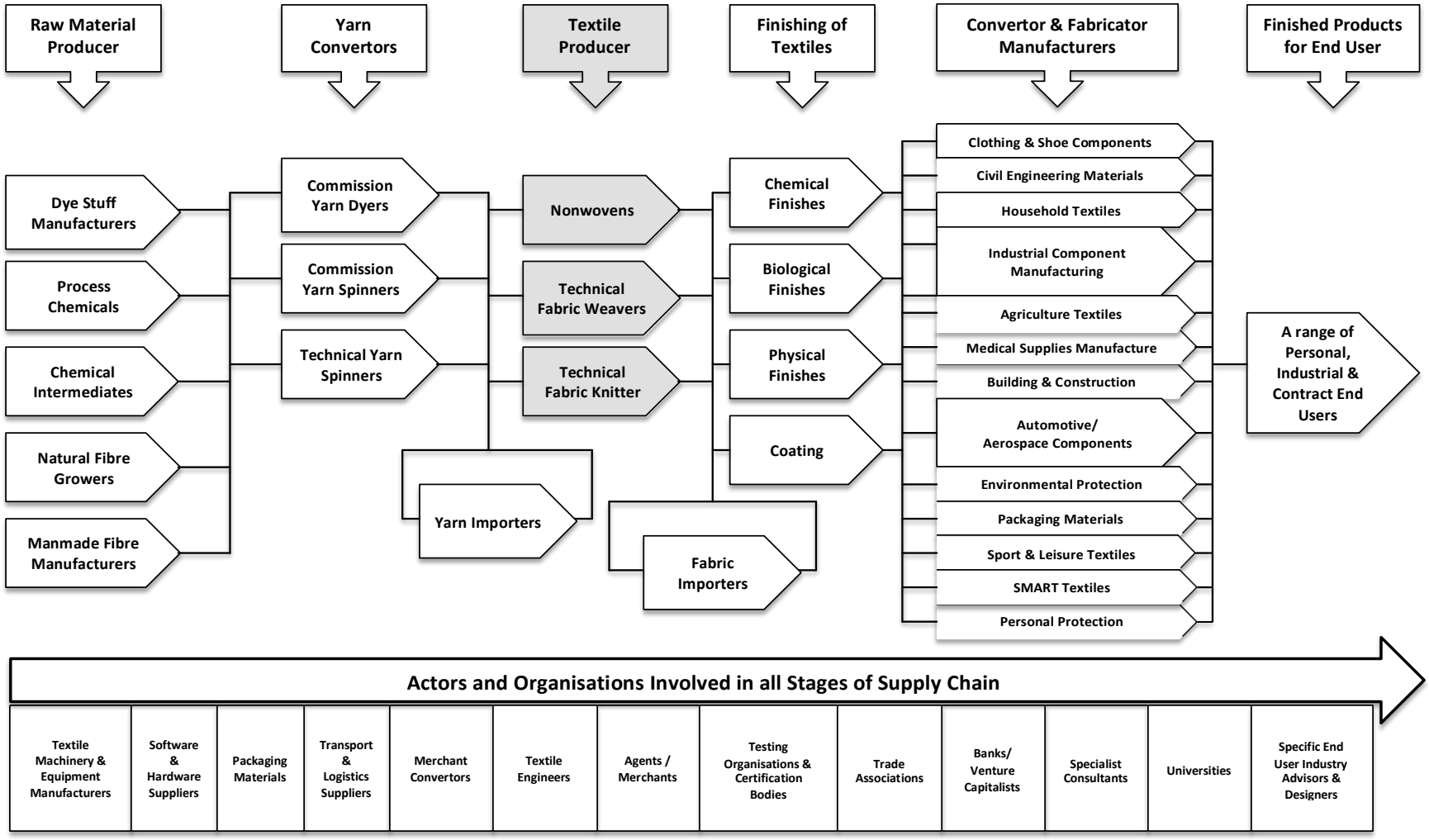
TT firms draw on a smaller workforce, compared to the traditional textile industry that was dominated by large companies (Dicken, 1986), but their skill base is more complex, diverse and consists of medium and highly skilled employees (Christopherson and Clark, 2007). TT firms require an increasingly skilled labour force to operate the latest manufacturing equipment and develop sophisticated TT fabric, as well as traditional textile skills with specialist knowledge and experience (Kalafsky, 2007). During the heyday of textile manufacturing (1970s and 1980s), investments in training programs were made by government and large textile firms (Christopherson, 2009). Thus:

> *"Quite a lot of our management team and our technical people are in their early fifties or late forties, who when they were young went through some sort of properly structured college, Derby used to run a course for weaving technicians and weaving skills"* (Interviewee 1, E-M-[Narrow]Weaver-5, 2013).

Combined with on the job training, traditional textile employees developed a learnt craft (Bryson *et al.*, 2008). UK TT firms have benefitted from these previous investments through consolidation of the industry, as they have recruited long-serving traditional employees. Firms now claim to employ the highest skill base they have ever had (E-S-Knitter-5, 2013).

A highly skilled workforce in UK TT firms contains a blend of inter-disciplinary degree level expertise (Foresight, 2013; Hansen *et al.*, 2013; Kalafsky, 2008). Firm's micro labour pool of employees includes textile technologists and chemical scientists for product development and fabric analysis, and engineering technicians for process and machinery developments: *"for example a customer was buying 3 metre and 2 metre fabric and trying to put it together to make a 5 metre felt, well we came along and made a 5 metre machine to do it*" (E-M-Weaver-12, 2013). In this case, engineering staff of the firm worked with machinery and equipment suppliers to modify and develop their own equipment to meet the requirements of a particular customer.

Figure 4.1: Technical Textile Supply Chain: Actors and Organisations



Source: Adapted from DRA (2001)

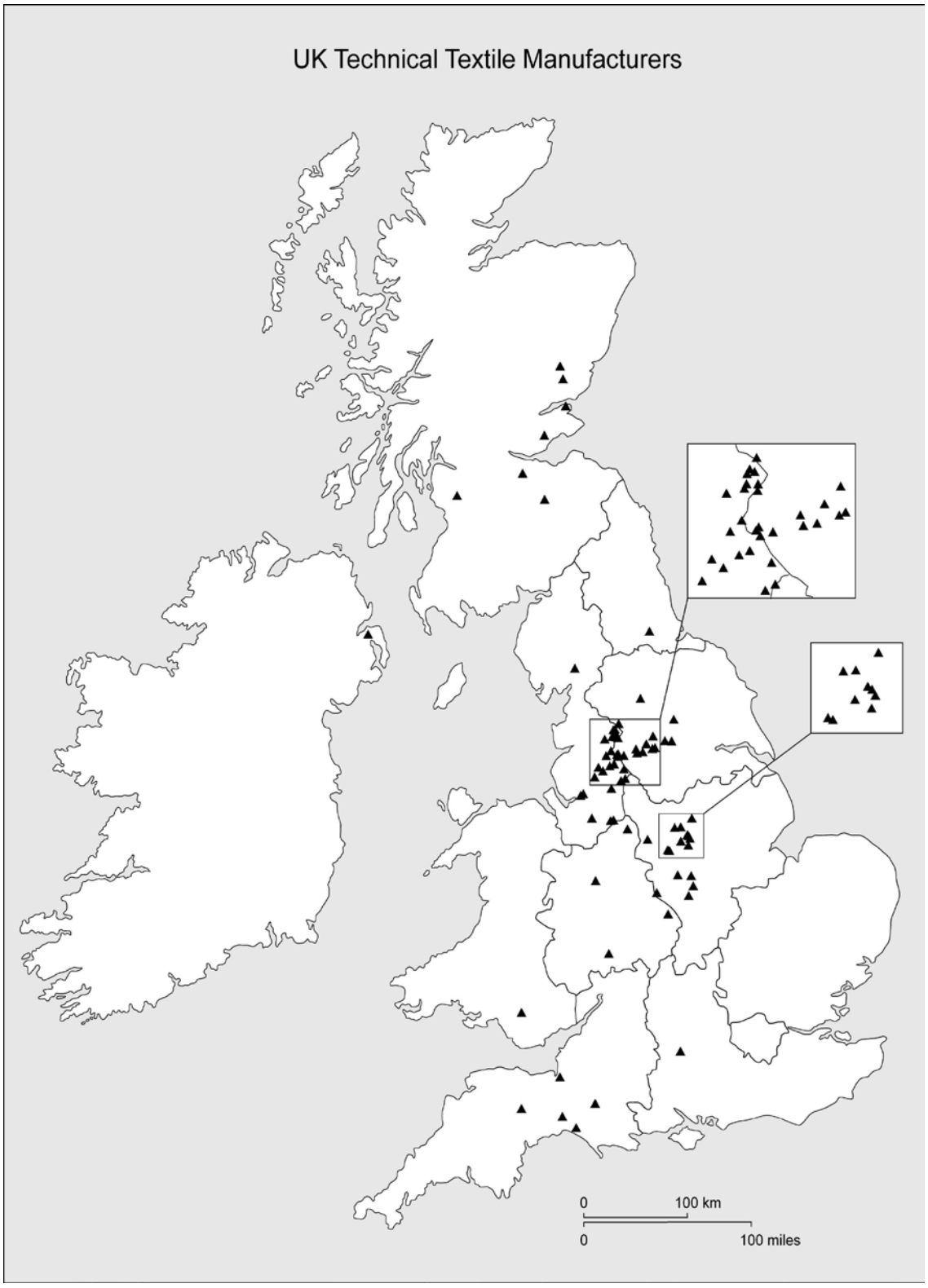
The spatial formation of the traditional textile industry in the UK was particularly geographical; factories located where there was available waterpower, mild temperatures and high humidity, as 'the damp atmosphere made spinning and weaving easier' (Fowler, 2003: 2). These areas included Lancashire, West Riding of Yorkshire, the East Midlands, Wales and the Scottish Lowlands (Alliance, 2015). The geography of UK TT firms reflects the historic evolution of the UK textile industry (Figure 4.2). The firms interviewed and included in this study are located across the UK, with the greatest number of firms located in the traditional textile regions of the North West (13/40) and the East Midlands (10/40) (Table 4.2).

Table 4.2: Location of UK Technical Textile Firms Interviewed

Region	Number	Percentage (%)	Weaving	Knitting	Nonwoven	Bobbinet
North West	13	32.5	8	2	3	0
East Midlands	10	25	4	5	1	0
Yorkshire & The Humber	5	12.5	4	0	1	0
South West	3	7.5	2	0	0	1
West Midlands	2	5	1	0	1	0
Scotland	5	12.5	4	0	1	0
Wales	1	2.5	1	0	0	0
Northern Ireland	1	2.5	0	1	0	0
Total	**40**	**100**	**24**	**8**	**7**	**1**

Source: Interview Data 2012-2013.

Figure 4.2: Geographical Location of UK Technical Textile Manufacturers



Source: Appendix D provided the sources of the firms mapped

The location of the UK TT industry is derived from two mechanisms of spin-off dynamics and agglomeration economies (Boschma and Wenting, 2007). First, spin-offs defined as 'new firms founded by former employees of incumbent firms in the same industry' (Boschma and Wenting, 2007: 215) tend to locate in the same region as their parent company (Klepper, 2007). The reason for co-location between spin-offs and their parents can be explained by the second spatial mechanism, agglomerative economies. Boschma and Wenting (2007: 217) have adopted Myrdal's (1957) perspective on the process of cumulative causation to explain agglomerative economies:

> 'The more firms locate in a region, the more diversified the local labour market becomes, the more suppliers can specialise, the higher local demand, the better the infrastructure, the more attractive the region becomes for newcomers, leading to more firms, etc.'

The mechanism of agglomeration economies develops advantages for firms concentrated in specialised industrial centres to exploit (Boschma and Wenting, 2007; Gabe and Abel, 2012). Advantages include access to pre-existing assets of skilled labour (Christopherson, 2009) and the potential of knowledge spillovers from the emergence of new firms with new technological developments in textiles (Boschma and Wenting, 2007), which enable firms to 'foster processes of diversification into new technologies and markets' (Foresight, 2013: 126). The UK TT industry has path dependent capabilities of skills, knowledge and experience embodied in the local labour pool, which is spatially immobile and 'sticky' to regional textile locations (Storper and Walker, 1983). This is reinforced by firms asserting,

"there isn't any economic reason for being here apart from the expertise and skill base that we have" (N-S-Knitter-1, 2012).

TT Products and Production Process

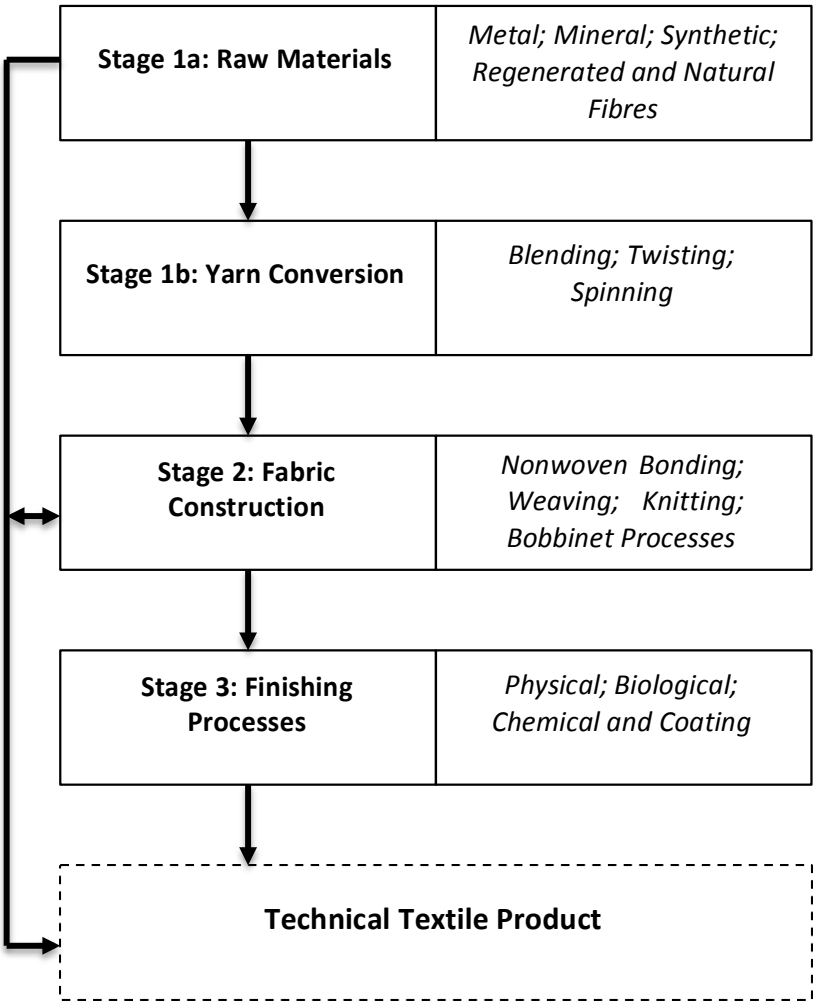
TT products are mostly *"designed from scratch with the customer"* (N-S-Weaver/Knitter-1, 2013) for firms to deliver a unique textile solution (Heimbach, 2013). UK firms produce TT through precision engineering (O'Mahony, 2007), which involves manipulating and blending several and varied technical attributes: the textile fibre, manufacturing process and finishing techniques (Section 1.3):

> *"There are so many different elements in the fabric… it's the very specific specification of each textile so right from the yarn type, the twist, the ply, the fibre type, the anti-static properties, the weave pattern, the construction of the fabric, the way we finish it, it's engineered, it's a fabric which fulfils a specification… we know to get that performance we have to weave the fabric in that weave pattern but we also need to specify that particular yarn from that particular supplier, so it's often a very demanding technical performance we're trying to achieve at the end"* (N-M-Weaver-4, 2013).

There are many different combinations of technical attributes from the textile fibre chosen to the finish process applied (Table 1.2). These technical attributes are purposely blended for a TT fabric to interact and perform in specific environments and applications (Byrne, 2000). For example, Kevlar® is a synthetic, lightweight and flexible fibre, which is five times stronger than steel. Firms can engineer Kevlar® to be either firmer for bullet- and stab-resistant body armour (Eason, 2009), or softer for cut-resistant pullover jumpers for glass manufacturing employees, using chemical finishes (E-S-Knitter-7). There are three key

stages of UK TT firm's production process (Figure 4.3): raw material and yarn conversion, fabric construction and finishing processes.

Figure 4.3: Three Stages of UK Technical Textile Production Process



Source: Adapted from DRA (2001: 31) and Eason (2009: 36-48)

Stage 1: Raw Materials and Yarn Conversion

The production process of TT begins with firms sourcing fibre (both natural and artificial) from raw material producers (Figure 4.1) (Byrne, 2000). Standard fibres and yarns

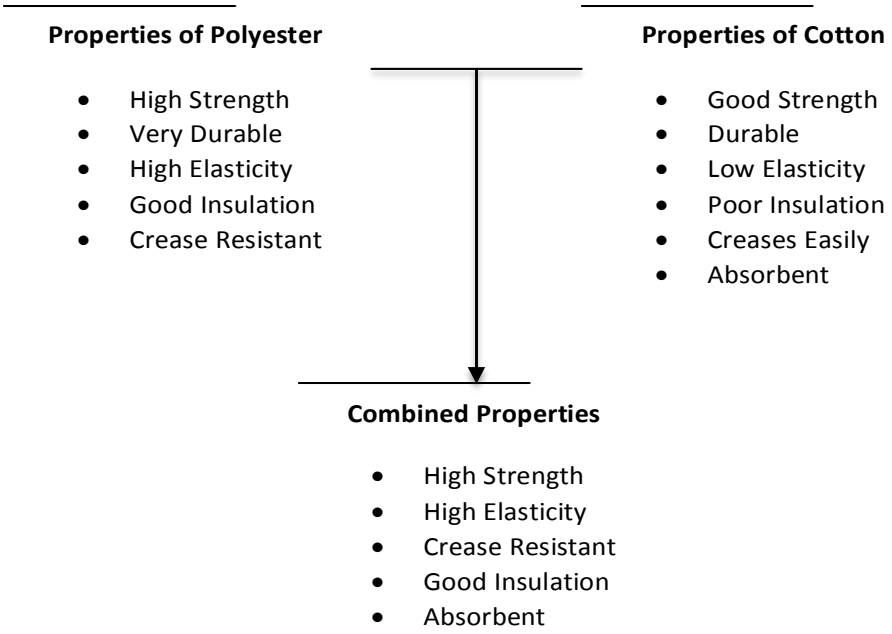
(especially natural yarns of cotton and wool) are mainly sourced from low-cost locations of the Far East and Eastern Europe (Eason, 2009). Whereas, technical fibres are sourced from Europe, the USA and Japan (Byrne, 2000):

> *"Technical fibres tend to be produced in Japan, Europe or the States and they might be spun in any of those places, but generally* [our] *technical yarns will tend to come from Europe"* (E-S-Weaver-6, 2013).

Technical fibre suppliers are predominately chemical TNCs that research and develop technical fibres, which are branded and certified for their performance properties (Braddock-Clarke, 2007a). For example, Kevlar® is a registered trademark developed by USA chemical company DuPont (Braddock-Clarke, 2007a). These corporations supply technical fibres from various manufacturing facilities localised to TT manufacturing centres of the UK, France, Germany, the USA and Japan (Byrne, 2000). UK TT firms source fibre from their nearest supplier site, for example, Japanese company Toray, supply carbon fibre from their manufacturing facility located in France (N-M-Weaver-1).

The fibre is converted to yarn by fibre suppliers or sub-contracted to yarn convertors located in the UK, France and Germany. UK TT firms do not produce the fibre or the yarn, but they blend yarns produced by their yarn suppliers. The most recognised blend is 'polycotton' that combines the properties of polyester and cotton (Figure 4.4).

Figure 4.4: Properties of Polycotton



Source: Adapted from Eason (2009: 41)

UK TT firms typically buy yarn in its single form to blend or twist multiple yarns together:

> *"Glass fibre is made in filament form… now the white one is a different chemistry to the green one, it's got different sizes, different thickness, different chemical structures so it might mean it has higher temperatures, and what we're doing here is we're blending together glass fibres and we're giving them texture, we're adding volume, to allow them to be bulky… by changing the* [thickness]*, it changes the performance of the glass because it takes out different frequencies of sound, so I'm able to say right I'll make you an* [acoustic] *fabric out of five ends of this, three ends of that and two ends of this, we're able to blend together the fabric"* (N-M-Knitter-3, 2013).

Many different innovation processes occur in which the raw material, the fibre, is transformed to produce a TT product (EEF, 2013; Sundbo, 1995). There are initial innovations in the fibre by the chemical suppliers, which develop different fibres to produce different yarns with inherent chemical structures (Braddock-Clarke, 2007a; Brown,

2005; O'Mahony, 2007). UK TT firms then further innovate the raw material through their own production process. Firms blend yarns that combine the different properties of each yarn to enhance and improve the technical function of a TT fabric (Eason, 2009). In this case, the firm can change the acoustic performance of an automotive exhaust system by the TT fabric component. This firm develops a specific blend of glass fibre for each TT component produced, which has an inherent chemical structure to absorb sound. This enables the firm to ensure that their textile component performs, by controlling the decibel level of the exhaust system required by automotive manufacturers (N-M-Knitter-3).

Stage 2: Fabric Construction

UK firms construct TT through methods of nonwoven bonding, as well as the traditional techniques of weaving, knitting and bobbinet processes (see glossary for full definitions). Each manufacturing process type has different properties (Section 1.3) and determines what type of fabric is produced (Table 4.3). The most frequent manufacturing process type amongst UK TT firms is weaving with 60 per cent (24/40) of firms; 27.5 per cent (11/40) of firms have knitting manufacturing processes and 25 per cent (10/40) have nonwoven processes. There are overlaps in the manufacturing process type, with 12.5 per cent (5/40) of firms consisting of multiple processing types. Two firms have combined both weaving and knitting processes (E-S-Weaver/Knitter-1, 2013; E-S-[Narrow]Weaver/Knitter-2), another two firms have combined weaving with nonwoven processes (E-M-Weaver/Nonwoven-1; E-M-Weaver/Nonwoven-2), whereas one firm has all three of the main manufacturing processes (E-M-Weaver/Knitter/Nonwoven-1).

Table 4.3: Technical Textile Production Technique, Attributes and Application

Manufacturing Process	Frequency of Firms with Manufacturing Process Type	Attributes of Fabric Type	Examples of Possible Product Applications
Nonwoven	10	Firm, Permeable, Strength, Lightness, Softness, Absorbent, Thermal	Filtration, Medical Dressings, Sanitary Products, Geotextiles, Thermal & Acoustic insulation, Composites.
Weaving	24	Strength, Absorbent, Firm, Flat, Stability	Composites, Military Apparel, Filtration, Industrial Belting, Ribbons, Webbing, Seatbelt, Harnesses.
Knitting	11	Elasticity, Flexible, Lightweight, Thermal Properties	Composites, Sports Footwear, Medical Supports, Infra Red Reflective Meshes, Breathable Outdoor Clothing.
Bobbinet	1	Diagonally Stable, Durable, Sheer, Light, Strength, Consistent	Parachute Skirting, Safety Nets, Light Diffusion Screens for Film and Theatre, Radar Reflective Fabric for Military Decoys.
Total	**46**		

Source: Interview Data 2012-2013, (Brown, 2005; Eason, 2009; O'Mahony, 2007).

Weaving is the oldest textile production process and the technology has not noticeably changed (Burton, 2013):

> *"Weaving is a traditional craft and over the years, apart from the technology, not a lot has changed. You're still taking a natural fibre… and we're creating a warp which forms the length if you like of the fabric and across the warp we're passing the weft, and the basic process of weaving won't have changed in hundreds of years"* (E-M-Weaver-8, 2013).

The machinery and equipment of firms is path dependent; it is based on the decision of previous owners and the available equipment and experience of labour at the particular

time and space a firm was established (Boschma and Frenken, 2006; Martin and Sunley, 2006):

> *"We've got quite a high level of capital investment to weave fabrics…* [and we can't] *suddenly become a knitting company for example, as our expertise is in weaving, it just requires too high an initial investment into a market that we don't know and in all honesty we don't have the relevant* [knitting] *skills"* (E-M-Weaver-7, 2013).

The production process used by a firm is determined by path dependency that is a reflection of their inherited capital investments or sunk costs in equipment, skills, product and customer base (Barney, 1991), and reflects the time at which equipment was purchased. A proportion of the firms interviewed (14/40) that were established before the twentieth century are weavers, in comparison to those that were established in the twentieth century, which have newer textile processing technologies of knitting and nonwoven techniques (Section 4.3).

Stage 3: Finishing Processes

Finishing (coating, laminating, chemical treatments) is the last process in TT production (Figure 4.3) and is important for the performance of the fabric (Braddock-Clarke, 2007b):

> *"For technical textiles, a fundamental part of the* process, [is] *the fabric finishing treatments, it's critical to the performance of the textile"* (E-S-Knitter-5, 2013).

Finishing adds value as it provides a fabric with additional technical features. Applying a finish can make a textile windproof, waterproof, breathable, stretchable, durable, flexible, flame-, radiation-, heat-, ultra-violet-, and stain resistant, anti-bacterial and sterilised (medical and healthcare applications) (Braddock-Clarke, 2007b).

Finishing processes are undertaken in-house by most UK TT firms (30/40). Firms that do not have the finishing equipment or skills to finish a textile (10/40), or apply a specific finish (flame retardant coating), will outsource this last process to suppliers (textile finishing or coating firm), customers, competitors or another business unit in a group company:

> *"Parachute sheets are often five metres wide, we can't finish five metre wide fabric in the UK, but we can finish it in Switzerland,* [our parent company] *have got a big finishing machine which is 5.3 metres"* (E-M-Bobbinet-1, 2013).

This firm emphasises the different capabilities a firm possesses and what production processes they can or cannot undertake depending on the equipment they have (Bryson and Rusten, 2011). The outsourcing of production is not only isolated to the finishing processes but can occur at any stage of the production process:

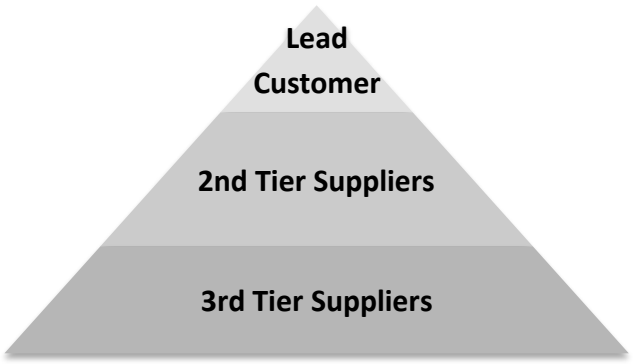
> *"E-L-Knitter-8 are looking at brushing and laminating some fabric I make, although we've got the same technology they can't handle a certain sort of yarn which I can, which is difficult to handle… so they're going to be processing some of my fabric"* (N-S-Knitter-1, 2012).

This firm describes how they are knitting some fabric for E-L-Knitter-8 in return for finishing processes on their own fabric. This explains how some firms have to outsource particular production processes externally to acquire the assets and skills they do not contain within the firm (Barney, 1991; Wernerfelt, 1984). The 'exchange' of production processes by firms to utilise each other's capabilities further emphasises the complexity of the UK TT production process.

UK Technical Textile Customers and Markets

UK TT firms are often third tier suppliers to convertors and fabricators involved in the further manufacture of fabric components (second tier suppliers) (Figure 4.5). The lead customers are those that the UK TT firms primarily service, with specific textile requirements followed. Lead customers are the final product manufacturers or brand leaders that control, govern and regulate the supply chain by selecting and specifying all of the suppliers, including UK TT firms (Gereffi *et al.*, 2005). Key lead customers of UK TT firms include Ford, Volkswagen and Jaguar Land Rover as Original Equipment Manufacturers (OEMs) in the automotive market and Rolls Royce, Airbus and Boeing for the aerospace market.

Figure 4.5: UK Technical Textile Firms Customer and Supplier Structure



Source: Author (2015)

There is increasing complexity in identifying UK TT markets (Alliance, 2015). As firms continue to innovate and develop sophisticated TT products, the further penetration of

textiles as integral intermediate components has expanded (DRA, 2001). Firms serve diversified markets, producing TT for an array of industries. For example, E-M-[Narrow]Weaver-1 produces narrow fabrics and elastic webbing for aerospace, military, marine, leisure, industrial and medical applications.

The key markets for UK TT firms are automotive (20 per cent), aerospace (17.5 per cent), industry (17.5 per cent) and interior (10 per cent), with the other 35 per cent share divided between military and defence, sport and leisure, medical and healthcare, protective clothing, construction, wind energy, wig and hairpiece and packaging (Table 4.4). The automotive market is the largest primary market for firms, which has also been a key market for the development and expansion of textiles used for technical applications (Byrne, 2000). For example, the automotive industry uses fifteen to twenty square metres of textile surfaces (excluding carpet) in the average car, just for acoustic insulation (O'Mahony, 2007).

UK TT firms have strong export markets, with 98 per cent (39/40) operating overseas. Significantly, two third of firms (27/40) receive a larger share of sales and turnover from their export markets than their UK markets (Table 4.5). Firms export to an average of forty countries, with key customers located in western Europe (particularly France and Germany) and the USA (UKTI, 2011b). To expand and continue to grow their share in export markets, firms are beginning to develop a stronger presence in the Far East and Eastern Europe where a lot of assembly manufacturing operations have relocated to (Dicken, 2011).

Table 4.4: UK Technical Textile Key Markets

Market	UK TT Firms Product Applications	Number of Firms with Primary Market (%)	Total Number of Firms Operating in this Market (%)
Automotive	Airbags, seatbelts, vehicle exhaust hose reinforcement, composite reinforcements for automotive bodies.	8 (20)	19 (47.5)
Aerospace	Composite reinforcements for wings, doors and engine components, overhead lockers, ejector seats, interior panelling.	7 (17.5)	14 (35)
Industry	Paper machine clothing, food conveyor belts, filtration, and insulation.	7 (17.5)	21 (52.5)
Interior	Upholstery (flame retardant, stain repellent), carpet underlay, office seating.	4 (10)	9 (22.5)
Military & Defence	Parachutes, bomb blast curtains, body armour.	3 (7.5)	17 (42.5)
Sport & Leisure	Climbing harnesses, sport surfaces, sport clothing, outdoor wind and waterproof jackets, wicking fabrics.	3 (7.5)	16 (40)
Medical & Healthcare	Technical wound care dressings, artificial limbs, joint support and restraints, wheelchair seating, medical mattresses.	3 (7.5)	12 (30)
Protective Clothing	Flame resistant, radiation, heat protection, bulletproof, stab protection.	1 (2.5)	17 (42.5)
Construction	Chemical impregnated reinforcements for walls, roofing and flooring.	1 (2.5)	9 (22.5)
Wind Energy	Composite reinforcements for wind blades.	1 (2.5)	4 (10)
Wig & Hairpiece	Wig net for inserting hair in the manufacturing of wigs.	1 (2.5)	1 (2.5)
Packaging	Ribbon decoration on retail presentation boxes and food products e.g. cake decoration.	1 (2.5)	2(5)

Source: Interview Data 2012-2013.

Table 4.5: UK Export Market Turnover

Export Market Turnover (%)	Frequency of Firms
Less than 50%	12
50% to 80%	23
More than 80%	4
Total Firms	**39**

Source: Interview Data 2012-2013.

This section has identified the key characteristics of the UK TT industry. UK TT firms are producers of bespoke TT intermediate components for a wide range of markets, specifically, the automotive and aerospace industries. They are SMEs located in traditional textile regions, to take advantage of agglomerative economies and path dependency processes, in particular to exploit the skilled labour pool, existing equipment and machinery, buildings and some customer relationships that pre-exist to the TT industry (Boschma and Wenting, 2007; Christopherson, 2009). The next three sections examine the history and adaptation processes of these firms to enter into the manufacturing of TT. The next section investigates the attributes of these firms, which diversified to TT; in particular it examines the formation of the companies and their speed and degree of adaptation to TT.

4.3 Industry Emergence: Established and Newly Created Firms

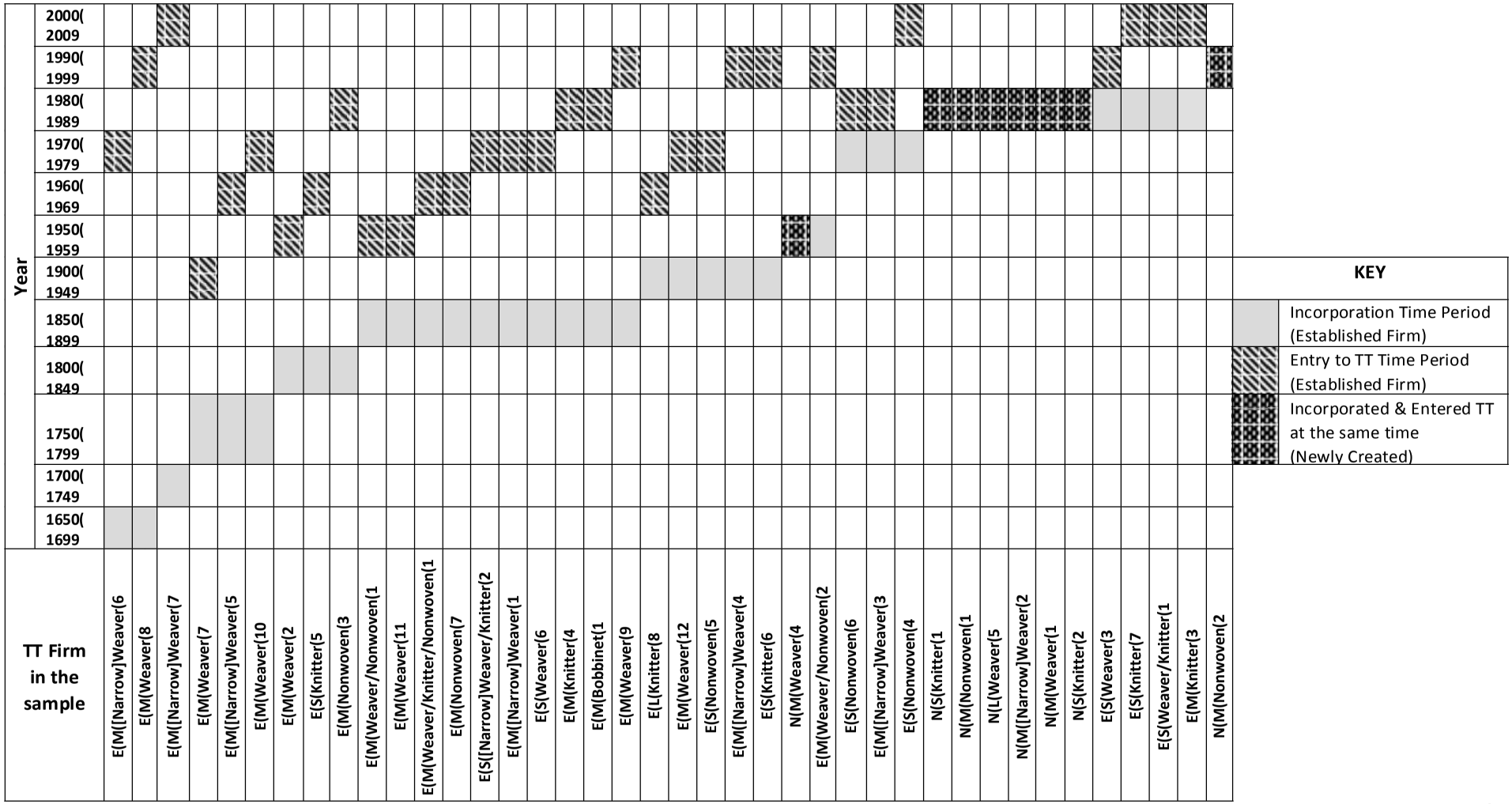
Variation, defined as any departure or change from current routines, traditions, organisational forms and competences (Aldrich and Ruef, 2006), involves 'the creative

capacity of economic agents and the creative function of markets' to drive economic evolution and adaptation (Boschma and Martin, 2010: 5). The emergence of new industries is driven by the micro-behaviour of an evolving population of firms (Boschma and Lambooy, 1999; Essletzbichler, 2009; Nelson and Winter, 1982). The trajectory of the UK textile sector to a new sub-sector of TT is hence linked to the trajectory of firms in this new industry (Boschma and Martin, 2007; Schamp, 2005).

The UK TT industry emerged through the adaptation and activities of two groups of firms, which were identified through the interviews. Group one included 80 per cent (32/40) of firms, which were identified as 'Established Firms', and group two included a smaller population of firms (20 per cent) that were identified as 'Newly Created Firms' (8/40). Throughout the remainder of the analysis, the forty firms are differentiated between these two groups by their identification code (Figure 3.2).

Newly Created Firms were established between 1950 and 1998 and began in the production of TT when they were incorporated, the start-up or formation of the company. The Established Firms did not begin with the manufacture of TT (Table 4.6). The table shows the time period of when each of the firms was incorporated and when they began to produce TT products. There is a time lag for 80 per cent (32/40) of the firms between when they were incorporated and when they entered into the production of TT. For example, over half of the Established Firms (19/32) were incorporated before the twentieth century (1665 - 1898) and adapted to TT between the 1940s and 2000s.

Table 4.6: Matrix Time Period Between Establishment of Firms and Entry to Technical Textiles



Source: Interview Data 2012/2013.

The Established Firms adapted their original business activities, which included non-fabric production and non-manufacture business activities, to begin manufacturing TT. This was due to these firms experiencing price-based competition from firms located in low-cost textile production locations (Bryson and Taylor, 2010). The majority of firms (26/32) entered into the production of TT from fabric production, with 53.1 per cent (17/32) of firms originally in the production of woven fabric for apparel applications and some light industry (Table 4.7). Mature and old industries can become insular and inward-looking by suffering from negative consequences of path dependent developments, earlier product innovations and market decisions that have become rigid, inflexible and lost dynamism (Hassink, 2010; Martin and Sunley, 2006). The Established Firms engaged in 'renewal' by innovation and technological developments to diversify the UK textile industry to TT and avoid a negative 'lock-in', where firms become stuck on an inefficient and uncompetitive path (Hassink, 2010; Martin and Sunley, 2006).

The formation of a new industrial path for firms may not always be strongly connected to their previous economic activities (Fornahl *et al.*, 2012). Six of the TT firms explain how different pathways are possible, as these firms have unusual and complex origins. A paper manufacturer and a manufacturer of textile machinery evolved into manufacturers of TT. Three textile merchants of TT products (glass fibre; protective clothing) and a product development company all introduced manufacturing capabilities, to enter into the production of TT.

Table 4.7: Established Firms Original Production and Business Activities

Production and Business Activities		Applications	Total Firms
Fabric Production	Woven Fabric	Apparel, Military Uniforms, Tartan, Industry; Jute & Linen for Industry & Packaging; Carpets; Webbing for Ribbons, Haberdashery, Corsetry, Shoes, Tufts and Piping in Beds	17
	Knitted Fabric	Apparel; Loudspeakers Material	4
	Felt	Apparel, Slippers, Craft, Industry	3
	Bobbinet (Machine-Made Lace)	Apparel	1
	Netting & Rope	Industry, Fishing	1
Non-Fabric Production	Paper Manufacturing	Wallpaper, Bookbinding, Packaging (Whiskey Boxes, Small Electronic Device Boxes, Fashion Retail Bags)	1
	Textile Machinery Manufacturers & Garment Assembly	Automated Textile Production Equipment; Apparel	1
Non-Manufacture Business Activities	Research & Product Development	Healthcare, Orthopaedic and Industry Textiles	1
	Textile Merchants	Wholesale & Distribution of Apparel, Hairnets, Industrial Netting, Protective Clothing, Glass Fibre	3
		Total Firms	**32**

Source: Interview Data 2012-2013.

Firms benefitted from the shutdown of some textile firms to acquire their suppliers or textile production equipment to continue their supply as 'merchants' or experiment and develop new TT innovations.

> *"This mill as a spinning company closed, so they offered this mill to buy or to rent… this company were buyers and sellers of TT into the UK market…* [And] *the company just left, closed the door, turned the machines off, closed it, so when the owners took over the building they had the spinning frames, so all of a sudden this stuff that they were buying in Eastern Europe was made out of some stuff that they could potentially make here, 'what shall we do with it?' 'Don't know let's put some stuff on this machine and see what happens'"* (E-M-Knitter-3, 2013).

The closure of some firms in the textile industry has led these firms to experience 'path breaking', with chance or serendipity enabling firms to initiate a new industrial development path (Fornahl *et al.*, 2012). To clarify, market changes and deindustrialisation in traditional textiles led to a loss of suppliers for these firms, but it also provided the availability and opportunity of existing and redundant capital to complement their existing capabilities and knowledge on textiles, to enter TT (Nelson and Winter, 1982; Wernerfelt, 1984).

The group of Established Firms have or are still adapting to TT gradually, as 14 firms are still producing a proportion of conventional textiles:

> *"I would say in 1990 when I joined the business we were about 20 per cent TT and 80 per cent traditional and then probably in the next ten years it flipped to 80 per cent technical, 20 per cent apparel because that's where the opportunities were and today we're about 90 per cent technical. We still do a little bit of silk, so we've probably got 10 per cent in most traditional markets"* (E-S-Knitter-5, 2013).

The above firm has produced silk for the lining of gloves since the nineteenth century by appointment to the Queen. The firm's competitive advantages of heritage and quality has led to a continued demand from the luxury fashion brand Chanel for the production of this traditional textile product. The demand for this product by Chanel is dependent on the relationship between the firm and this particular client, this provides the firm with a secure profit line and an inimitable competitiveness strategy based on this client-based relationship (Chapter 5) (Bryson *et al.*, 2008).

The degree of adaptation by the group of Established Firms is summarised in Table 4.8. The majority of the firms (18/32) have fully adapted to TT but there is still 35 per cent (14/40) of the total sample of TT firms, which are still producing non-TT products alongside a growing proportion of TT products (Table 4.8). The speed of firms adaptability to 100 per cent adjustment of TT production and economic activities depends on each firms individual path trajectory (Martin, 2010; Schamp, 2005). The adaptation process to TT could be hindered by a firm's path dependency that effectively restricts its capacity to change (Martin and Sunley, 2006). E-S-Knitter-5 (above example) managed to increase their degree of adaptation to TT from 20 per cent in 1990 to 90 per cent in 2013, but are still producing 10 per cent of non-TT products in the form of silk. This is due to the non-TT product being a differentiated product with a core customer, which is still providing the firm with a profit margin and balance between TT and older forms of textiles. The reasons and path trajectories of the other firms that have not fully adapted to TT is examined in Section 4.5.

Table 4.8: Percentage of Technical Textile Products in Established Firms Product Portfolio

% of Technical Textile Products	Number of Firms
100	18
90	5
80	3
70	2
60	1
50	2
40	1
30	0
20	0
10	0

Source: Interview Data 2012-2013

Newly Created Firms were purposely set-up on a new industrial path by engaging in the innovation and production of TT as spin-off companies (Martin, 2010; Martin and Sunley, 2010). In the 1980s, the UK textile industry was dominated by four firms (Courtaulds, Coats Patons, Tootal and Vantona Viyella), which accounted for over half of all textile employment (Dicken, 1986). This form of monopoly capitalism has disappeared from the British textile industry, as firms were taken over, closed or shifted production to low-cost locations. These larger firms were often the training grounds for entrepreneurs who established smaller TT firms; seven of the eight firms were established by employees of these larger textile consortiums who were *"forced to find their own way"* (N-S-Weaver/Knitter-1, 2013), as these large consortiums disappeared:

> *"My father found the company about 30 years ago, he used to work for a big mill for a large textile consortium in the UK, a lot of the textiles after the second world war began to decline and consolidate, so you had companies like Coats Viyella and Courtaulds that swallowed up a whole heap of small businesses. He worked in a fairly large mill which during the consolidation process was closed down in the early 1980s and… he decided to set up his own business, he saw the opportunity, so he took his skilled guys, half a dozen of them and they set this place up"* (N-S-Knitter-1, 2012).

Specifically, two of these firms had spun out from research departments of Courtaulds, a large British manufacturer of artificial fibres, chemicals and textiles. An entrepreneur that previously owned a carpet manufacturing firm and road haulage business utilised his market knowledge and personal networks to establish a TT firm (N-M-Weaver-4, 2013).

Similar to the photonics industry in New York (Christopherson and Clark, 2007), these new UK TT firms inherited routines and competencies from their parent companies and combined these capabilities and resources with prior experience, specific skill sets and learning, to 'spin out' of a declining textile industry with new and innovative TT technologies (Christopherson, 2009; Martin and Sunley, 2010). This highlights how the interaction of path dependence and path creation has instigated new forms of micro-economic behaviour by firms (Martin, 2010). This has led to the transformation of the UK textile industry by the emergence of a new industrial path in the form of a high value-added and innovative sub-sector (Boschma and Martin, 2007).

This section has identified two types of firms, which diversified from their original activities between the 1940s and 2000s, to enter into the production of TT. The first group, Newly

Created Firms, represents 20 per cent of UK TT firms interviewed that began in the production of TT when the company was set-up. The second group, Established Firms, contains 80 per cent of firms, which predominately entered into the production of TT from traditional textile fabric production. Established firms have gradually adapted to TT, with 44 per cent (14/32) of these firms still producing non-TT products. The next section begins to examine how firms have adapted to TT, by investigating the role of the UK government and industrial trade bodies in the formation of the UK TT industry.

4.4 Institutions and the Emergence of a UK Technical Textile Industry

Institutions, defined as containers of socioeconomic organisation (Amin, 2001: 1237), may include 'formal structures such as legal rules, property laws, state policies and technological standards, as well as informal habits, codes of conduct, organisational cultures and conventions that provide stability and inertia and guide individual action' (Essletzbichler and Rigby, 2007: 557). Evolutionary approaches emphasise the emergence of new industries, such as the TT industry that are shaped by, and require support and change from institutions (Boschma and Frenken, 2009). New institutions can be created and implemented by public intervention at the national scale to deliberately 'support and sustain the further growth of the new industry' (Boschma and Frenken, 2009: 155). Institutions (trade associations, research centres, universities, government funding) in western Europe have managed to develop and maintain key TT clusters:

> *"All the other European countries have technical textile groups at a national level who promote integrated, working together, collaboration between those companies,*

> *they're all connected with regional economic funds and they help each other to attract funding*" (E-S-Knitter-5, 2013).

The UK government, alongside textile trade associations and industrial bodies, attempted to play an influencing role in the formation of a TT industry:

> *"The UK government became interested in technical textiles around fifteen to twenty years ago, mainly as a result of the difficulties faced by traditional textiles businesses, who were seeing their market share collapse as garment makers ordered fabrics from offshore… By the late 1990s a number of industry bodies appealed to the then Labour government to support the industry.* [In 1998] *the government set up a body called the Textile and Clothing Strategy Group (TCSG). The TCSG produced a report* [in June 2000] *recommending that, amongst other things, technical textiles could offer solutions to the problems of import penetration, not by competing directly with imports, but by exploiting market opportunities presented by technical textiles"* (Steve Kay, Managing Director, NWtexnet, 2012).

The TCSG was a new institution to support the formation of the UK TT industry. It consisted of trade associations, manufacturers, retailers, unions and academia, which met on a monthly basis throughout 1999 to discuss and examine the challenges facing the UK textile industry and its future at the turn of the twenty-first century (TCSG, 2000). A strategy report entitled *'A National Strategy for the UK Textiles and Clothing industry'* was produced, with recommendations on how the industry could maintain its competitiveness in a global economy. The report recognised 'there are some areas of textile and clothing manufacturing in which the UK will never be competitive' but there are opportunities to be exploited in high value niche areas such as TT (TCSG, 2000: 6). The report recommended for the Department of Trade and Industry (DTI) to assist firms in the process to diversify into TT and to fund activities involving technology transfer and network development between manufacturers and higher education institutions (TCSG, 2000).

A Foresight report, also released in 2000 entitled *'Materials Futures'* underlined the importance of the TCSG report by demonstrating how the UK government support for TT had increased and been positive (Foresight, 2000). Actions taken included the creation of a Technical Textiles Innovation Fund of £2 million and the new Technitex Faraday Partnership involving Heriot Watt, Leeds and UMIST universities (Foresight, 2000), for research and knowledge transfer of the latest new technologies to firms in the TT sector (TechniTex, 2015b). Developments since this first public recognition of government interest in TT included Textiles Minster Patricia Hewitt releasing a report in 2001 entitled '*Government support for the textile and clothing industry*' and a website through the Department of Trade and Industry. This report investigated the progress of the UK textile industry since the June 2000 recommendations, which included £1 million investment into TT companies to develop a new range of products and materials and £2 million for retraining in the industry (DTI, 2001).

Supportive institutions, such as new trade associations, industrial bodies and university departments, were then created as an outgrowth of the development and recognition of the new TT industry in the UK (Boschma and Frenken, 2009). These institutions were encouraged to support firms in adapting to TT through innovation and skill funding initiatives, collaborative research projects and trade networking events. For example, the trade organisation NWtexnet, established in 1999 as part of the new materials research department at the University of Bolton, was contracted in 2003 by the Regional Development Agency to act as a cluster development organisation for the textile industry in

the North West of England (Appendix B). NWtexnet endeavoured to assist firms in the transition to TT through access to skill development activities and knowledge of new and emerging technologies. The organisation provided networking opportunities for firms to share best practice, learn how to adapt to TT and improve their competitiveness at quarterly IAB meetings (Appendix B). Successful TT firms were encouraged to share their experience of adaptation and best practices:

> *"We were invited to speak at NWtexnet events because we were one of the companies that were growing, we'd found a niche and we'd exploited it and the message to the textile industry at the time was for firms to find a niche and exploit it, and we were an example for firms to see 'look it can be done"* (N-M-Weaver-1, 2012).

The UK government did recognise the TT industry but institutions 'are often slow to form and perhaps even slower to adapt' (Essletzbichler and Rigby, 2007). UK firms were already established in TT before institutions took notice and attempted to provide industry support meaning that initiatives by institutions to encourage firms to adapt to TT 'by and large, proved unsuccessful' (DRA, 2001: 33). Firms subsequently, began to slowly disengage from these institutional cluster activities:

> *"We got involved… in various kinds of meetings and breakfast networking events organised but there was just no benefit for us. The idea was for the cross fertilisation of technology; we could learn from these guys and there would be synergies that we could all learn from, but* [we differ completely in our processes and equipment to the rest of the technical textile industry]*, there is no real advantage of doing that"* (E-M-Weaver-2, 2012).

Supportive UK TT institutions may have played an indirect role in stimulating some localised knowledge spillovers from these network events, which may have had an influence on

some firms in their ability to adapt to TT (Boschma and Frenken, 2009). However, the overall effect of institutions on firms adaptation to TT was minimal, as 'firms develop routines in a path-dependent and idiosyncratic manner' (Boschma and Frenken, 2009: 153).

This is similar to the Westmünsterland textile region in Germany where previous 'high degrees of state involvement at national and supra-national level' (Hassink, 2010: 453) kept labour-intensive traditional textile industries 'alive' by competition and trade policies of the MFA, training subsidies and attraction of FDI to prevent plant closure and conserve the industry (Dicken, 2011; Hassink, 2010; Hudson, 2002). However, weak institutional involvement of the textile industries in both Germany and the UK enabled renewal to be achieved, which has been shown by the quiet restructuring and diversification processes of firms to TT with little media, political or academic attention (Byrne, 2000; Hassink, 2010; McQuaid, 2005).

This section emphasises how the adaptation of firms entering into the production of TT is firm-based and independent of government and industrial trade bodies' supportive initiatives (Boschma and Frenken, 2009; Hassink, 2010). The next section examines the processes of adaptation undertaken by the firms, which has been influenced and driven by their path dependency, to become TT manufacturers (Boschma and Frenken, 2006; Martin and Sunley, 2010).

4.5 From Cotton to Carbon: Firm-Based Adaptation to Technical Textiles

Ever shifting markets and changing competitive dynamics in firm's external economic environments, demands firms to respond by the adaptation of their routines, the reallocation of firm's resources and capabilities to new organisational forms (Chakravarthy, 1982; MacKinnon *et al.*, 2009; Martin, 2010; Martin and Sunley, 2010). Adaptation enables firms to survive and compete in fluid, changing and new external economic environments (Boschma and Martin, 2007; Schumpeter, 1942). Since the 1980s, the number of firms that entered into the production of TT increased by 57.5 per cent (23/40) (Table 4.6). This was associated with first, the rise in price-based competition from low-cost producers, which undermined the competitiveness of firms producing non-TT:

> *"Cheap foreign competition was an issue ten to fifteen years ago, we had to get out of those garment making markets... if you've got a high labour element, the standard woven webbing just doesn't raise enough revenue, you need to be able to add more value to it"* (Interviewee 1, E-M-[Narrow]Weaver-5, 2013).

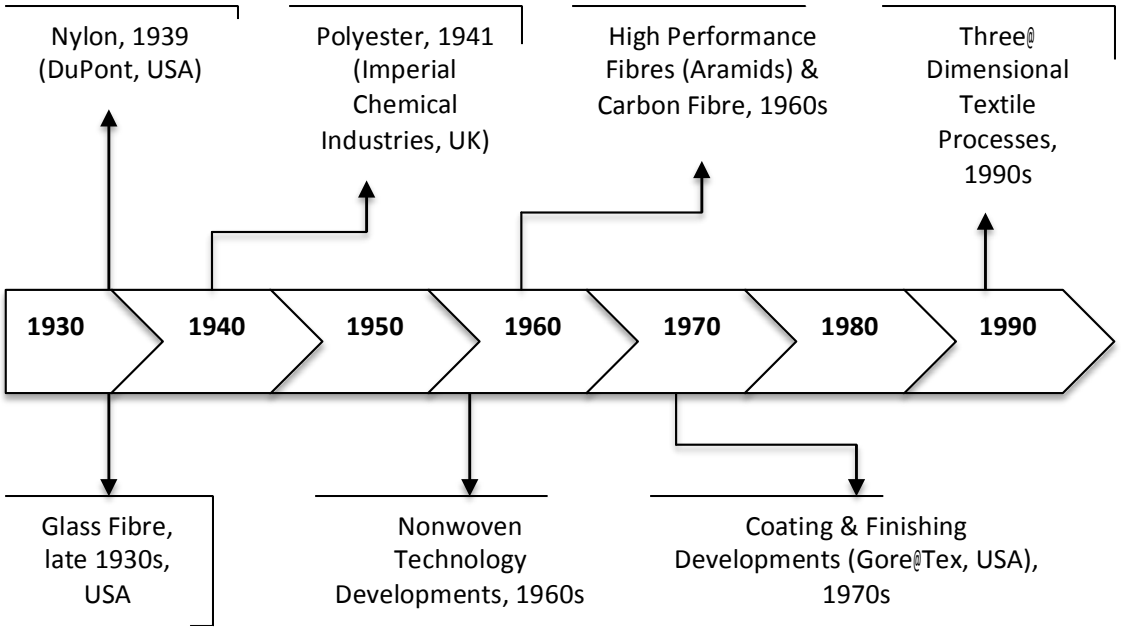
Second, the emergence of a UK TT industry caused firms to observe other firms that had already entered the sector and through knowledge spillovers from the mechanisms of agglomerative economies (Section 4.2), realise the opportunities and benefits to replicate and imitate these firms to enter into the production of TT (Dicken, 2011; TCSG, 2000):

> *"E-M-[Narrow]Weaver-1 are far more technical, and to be fair to them when we sat down 6-7 years ago it was the Personal Protective Equipment (PPE) industry that we were looking at and they were in it, so we've tread on their toes a little bit to* [enter this industry] *and that's what led us down the path to then opening the door… to go down the technical route"* (E-M-[Narrow]Weaver-7, 2013).

This firm is a narrow weaver and replicated another company with similar production routines, to guide its decision-making in which market to focus on to successfully adapt to

TT. Third, technological developments in textiles were a *"catalyst of change"* for firms *"from being a traditional textile organisation into TT"* (E-M-Weaver-2, 2012). The capability of firms to adopt new technology into their existing routines (Boschma and Lambooy, 1999) enabled them to withdraw from price-based competition, by moving up the value chain and produce TT for a range of sophisticated applications (Livesey, 2006). The introduction of technological developments in fibres, fabrics and textile processing equipment since the late 1930s (Figure 4.6) is associated with a gradual upward trend in the number of firms entering into the production of TT (Byrne, 2000; McQuaid, 2005).

Figure 4.6: Key Technological Developments in Technical Textiles



Source: (Braddock-Clarke, 2007a; Byrne, 2000; McQuaid, 2005; O'Mahony, 2007).

Entry to TT began in 1942 with firm E-M-Weaver-7 (Table 4.6), by request of the UK government to research and develop glass fibre, a new material at the time. The evolution of the UK textiles industry to TT has been driven by the 'dramatic impulses' of high performance fibres that were introduced by suppliers in the industry (Byrne, 2000: 8):

> *"We were* [one of] *the first aramid manufacturer[s] in the UK* [in 1975]*, we were one of the original DuPont partners in Europe for their aramid business…* [And] *Nomex® when we developed it in 1990, we actually worked with DuPont to develop the product"* (E-M-Weaver-10, 2013).

Large chemical companies like DuPont, which are leading producers of artificial fibres worldwide (Braddock-Clarke, 2007a), spent a lot of time approaching textile firms in the twentieth century and posing pressure to work in partnership. This partnership involved developing TT fabric from new fibres and to find a market outlet for these fibres (Braddock-Clarke, 2007a; Byrne, 2000). This required firms to innovate with new fibres and develop new product applications by incorporating the technical properties of the fibre:

> *"The first aramid fibre, which Nomex® came out of… a technology spin-off from the space program, and* [in the 1960s] *my father got some Nomex® yarn and he made one of the first properly high performance fire retardant fabrics, which he used in gloves* [for motor racing drivers]*, so it started off with the gloves, and then went into the balaclavas and then everything else"* (E-S-Knitter-5, 2013).

This company utilised the opportunity to adapt their silk gloving business to protective gloves from experimenting with aramids, which were commercially introduced in the 1960s and have been effective as high temperature resistance fibres (Quinn, 2010).

In the early nineteenth century, firms in the USA automobile industry 'were transformed by great technological changes' in new manufacturing methods, especially by the introduction

of the moving assembly line that increased the efficiency and speed of production (Klepper, 2002: 652). Comparable to the automobile industry, technological developments in machinery and textile processing in the twentieth century marked a second milestone of a determinant to TT:

> *"In the early 1960s the nonwoven technology was a new technology and our owner at the time was attending Leeds University, learning about this technology advancement. This sort of sparked his imagination and he decided to go into nonwovens for filtration, so that was a real change of direction for the business"* (E-M-Nonwoven-7, 2013).

This company decided to change their processing operations from weaving to nonwoven techniques to produce niche products for the filtration market and enter new markets requiring a technical nonwoven fabric.

Similar to the yarn and fibre suppliers, firms have been influenced to enter into the production of TT by equipment suppliers introducing new machinery:

> *"The prime supplier of knitting machinery to our factory… had developed a new machine process for making glass fibre, they were pushing that heavily amongst* [their] *existing* [customers] *and my Uncle picked up on it and thought well that might be an interesting way to survive, sort of move the business away from traditional textiles towards TT"* (N-M-Nonwoven-2, 2013).

Other advances in textile forming technologies that firms have adopted include warp and weft knitting, stitch bonding and modern braiding methods, and most prominently nonwoven techniques (Byrne, 2000). Firms have also adapted their existing machinery to produce new products. For example, E-M-Weaver/Nonwoven-2 adapted their weaving looms in the early 1990s to produce surfaces for sport and leisure industries, cricket

surfaces and carpet for outdoor bowling, as their traditional production in carpets was experiencing a persistent decline in market share. This firm adapted to TT by using an existing skill set and technology related to the carpet industry to provide them with variation in product and market (Bryson and Ronayne, 2014).

Technological changes in textile raw materials and equipment led to significant innovations in new TT products, which expanded the use of textiles in various products and markets. However, as McQuaid (2005: 13) states, the technological changes have occurred over the last fifty years but it was not until the 1980s that 'the rest of the world became more familiar with the existence and potential uses of these fibres and textiles, which resulted in exceptional growth in the field'. An important example is the adjustment to the medical and healthcare markets with the introduction of technical absorbent dressings (N-M-Nonwoven-1) and 'artificial ligaments, veins and arteries and skin replacement' textiles (Byrne, 2000: 13).

The growth in commercial examples of the potential end users of TT led to changes in consumer demand for new forms of textiles, which could be incorporated into new technologies and product applications (Byrne, 2007; McQuaid, 2005):

> *"In the early 1970s, we had a bit of [good] fortune that Rolls Royce were developing at the time the new current range of modern large aerospace engines, and they had a weight problem on the engine, everything had to get lighter and more efficient … one of our directors at the time spent a lot of time playing bowls and ran into a Rolls Royce engineer on a bowling green in Derby, and the guy turned round and said*

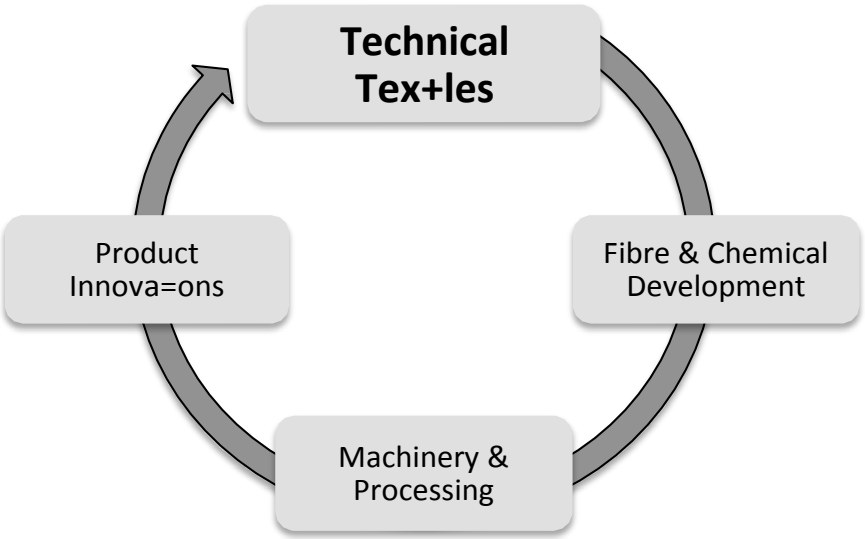
> *'look we've got a strength problem, we've got a weight problem, we've heard about this Kevlar® stuff, do you reckon there's anything in it for us?' and as a result of that conversation we got involved in working with Rolls Royce to develop, technically to trial test, make examples of the Kevlar® containment system which is now obviously current on various of their engines"* (E-M-[Narrow]Weaver-1, 2013).

This firm highlights the importance of chance meetings, in recognition of firm's path dependent informal and social relationships between employees of different firms (Granovetter, 1973; Power and Lundmark, 2004; Storper and Venables, 2004). E-M-[Narrow]Weaver-1 utilised the opportunity to adapt their existing textile products, which were losing market share in traditional apparel markets, and repositioned themselves into an advanced way of thinking and manufacturing for the aerospace market. Once firms had been initially guided into the production of TT by their customer's innovation requirements, they were able to expand into further TT markets (Boschma and Frenken, 2006; Nelson and Winter, 1982). This firm built upon their experience of processing and developing Kevlar® for Rolls Royce to developing fire-safety protective products for a second TT market, as Kevlar® has inherent flame- and heat-resistant properties (DuPont, 2015). Firms entering TT from consumer-led changes have occurred sporadically when a serendipitous opportunity has been presented, like the above example when a conversation between two employees from different firms occurred whilst playing bowls (Fornahl *et al.*, 2012; Martin and Sunley, 2006).

Firms have diversified to TT over a 70-year period between the 1940s and 2000s (Table 4.6). The transformation of the UK textile industry to TT has therefore been a gradual shift, with some key 'moments' of innovations in fibre, fabric and equipment, as well as demand for

new products by consumers, which were critical for the change (Hassink, 2010). New technological developments and innovations in TT are providing the industry with a continuous evolution cycle (Figure 4.7), which influences and assist the trajectory of a firm's path to be evolving rather than leading to a negative 'lock-in' (Boschma and Frenken, 2006; Martin and Sunley, 2006; Maskell and Malmberg, 1999b).

Figure 4.7: External Economic Environment Influences of Technical Textile Evolution

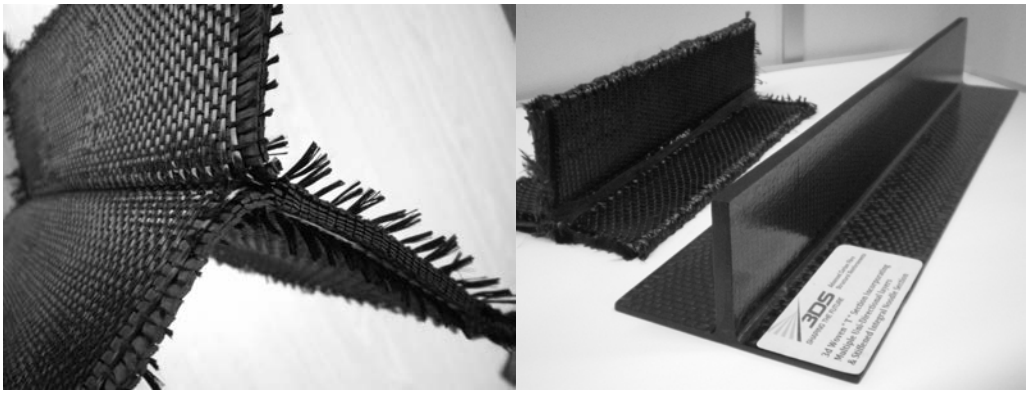


Source: Author (2015)

To exemplify, UK TT firms are increasingly focusing their efforts into improving their capabilities to produce fabrics for composite applications (E-M-[Narrow]Weaver-1). In partnership with equipment and machinery suppliers, UK firms are developing 3D weaving looms to *"weave shapes… that end up being moulded into solid composite parts"* for the assembly of planes, cars and trains (N-M-Weaver-1, 2012). The textile is first woven

incorporating multiple uni-directional layers as a flat fabric, before being cut open at one side to produce a 'T' section profile fabric (O'Mahony, 2007) (Figure 4.8).

Figure 4.8: Advanced Carbon Fibre 3D Structural Reinforcement Fabric



Source: Photographs by E-M-[Narrow]Weaver-1, 2013

This section has examined the drivers or explanations for *why* firms adapted to become manufacturers of TT. A combination and interaction of factors in firm's external economic environments has played an important role in determining the formation of TT. These included changes in the competitive dynamics of traditional textile industries, the development of a new sector that caused firms to become familiar with its existence and copy those that had entered the sector earlier, the introduction of technological developments in fibre and machinery by suppliers, as well as new products to the market by customers that required innovative textile components. The next section examines *how* UK firms adapted to TT in response to the external pressures discussed above, by

investigating the processes of firm-based adaptation that required specific resources and capabilities of the firms.

4.5.1 Adaptability to Technical Textiles: Resources and Capabilities

The adaptation process to TT required the reallocation of firm's resources and capabilities to new organisational forms (Chakravarthy, 1982). To adapt to the pressures of their external economic environment, which has been outlined above, firms acquired external resources of new equipment and fibre (Dicken and Malmberg, 2001; Yeung, 2005). The ability of firms to absorb these resources and develop adaptation strategies, the process of *how* and *when* firms decided to adapt to TT, has been heterogeneous and dependent on each firm's path trajectory (Martin, 2010; Schamp, 2005). Some firms have been more 'open' to adaptation, resulting in 100 per cent adaptation to TT (Section 4.3), whereas others haven't due to their path dependency (Boschma and Frenken, 2006). A firm's path dependency, previous decisions and settled patterns of behaviour, influences the current decision making of firms and their capabilities to break an existing routine and develop a new one (Aldrich and Ruef, 2006; Martin and Sunley, 2006; Nelson and Winter, 1982).

Some firms made the decision to commit to diversifying into TT by combining and utilising their existing capabilities of *"experience, knowledge and persistence"* (E-M-[Narrow]Weaver-1, 2013) to new forms of economic behaviour (Boschma and Frenken, 2006; Teece *et al.*, 1997). Whereas, others adopted the attitude of *"let's have a go at it or*

fold" (E-M-Weaver-12, 2013), as it was no longer an option to continue in high volume, low-cost textiles since most of these industries had departed overseas (Gereffi, 2005). A firm's decision to adapt to TT also depended on their market position in its established products. Firms that were earning above average returns on conventional textile products by developing competitiveness strategies related to heritage and brand (Bryson and Rusten, 2011), as E-S-Knitter-5 has with the supply of their silk lining to fashion brand Chanel (Section 4.2), may continue to produce this product (Barney, 1991; Schroeder *et al.*, 2002). Understanding the path dependency of firms can assist the RBV of the firm to explain why the performance of firms within the same sector, their degree of adaptation and competitiveness in TT, can vary over time (Hoopes *et al.*, 2003).

The main resources and capabilities required by firms to adapt to TT included financial strength (Klepper, 2002), highly skilled employees with the technical capability to produce TT (Christopherson, 2009; Makadok, 2001), a management team willing to change, and time; the organisational capital resources of planning, controlling and coordinating adaptation processes alongside their conventional economic activities (Barney, 1991). Significant financial investment and time has been required by firms to adopt new technological developments, meet product innovation requirements of customers, and ultimately enter into the production of TT:

> *"It's a very difficult sector and to go from zero to being a player* [is difficult]*, because where's your creditability, where's your background, where's your experience levels, you're trying to break into a market which is extremely difficult and you've got to be prepared to spend a lot of money and a lot of time"* (E-S-Knitter-7, 2013).

Typically entering TT was an expensive investment for the firms. They had to invest a substantial amount of capital, especially during the learning stage of experimenting and trialling samples with technical fibres, which can be £30 a kilo in comparison to nylon at £3 a kilo (E-M-[Narrow]Weaver-1). Firms had to have the financial resources available to enter TT (Klepper, 2002).

Financial assistance was provided to some firms, which played a determining factor on their adaptability to TT. First, customers that demanded new TT products, provided firms with investment into new equipment, materials and product development time (N-L-Weaver-5; N-S-Knitter-2). Second, large TNCs acquired six of the firms interviewed in the 1980s and 1990s, and directed investment into these firms to assist them in entering TT markets. These six firms were detected by TNCs and involved in a process of vertical integration and consolidation in the industry (Bryson and Ronayne, 2014; Warren and Gibson, 2015). Firms were acquired for their novelty, either because they had a similar production process (E-M-Bobbinet-1) that was complementary to the TNCs' product range, or because the firm's intermediate TT products met the characteristics of the customer's 'end product' (Martin and Sunley, 2006; Sayer, 2004). E-M-[Narrow]Weaver-6 was a producer of ropes and nets for the fishing, construction and aerospace industry. This firm was acquired by an aviation firm in 1979 and stripped all non-aviation related activities of the business, to focus on supplying products exclusively to the parent company.

TT is a different production process from mass produced and high volume orders, where *"miles of fabric are thumped out* [as firms are] *trying to be efficient on the production"* (E-M-Weaver/Nonwoven-1, 2013). TT is co-produced with customers; firm's research, design and prototype intermediate components to fit within assembled end products, which meet a customer's specific requirements (Alliance, 2015; Bryson and Taylor, 2010; DRA, 2001). These advanced sophisticated processes require a more complex and expert skill set (Christopherson and Clark, 2007). Firm's personal networks, technical skills and market knowledge (Christopherson, 2009), have been a determining factor for a firm's success into entering TT:

> *"We've gone down a deliberate business path to become a non-apparel company, but it's a niche business and most companies were not capable of making the leap from being a mass market outfit to being in a specialist market"* (E-M-[Narrow]Weaver-1, 2013).

A great deal of new TT product innovations, which enabled firms to enter TT markets, has come from key individuals within the firm. For example, a paper manufacturer became a fabricator of TT, due to a 'blue sky' innovation idea from a single employee *"to make a paper type material out of short chopped carbon fibre instead of wood pulp"* (N-M-Nonwoven-3, 2013). To diversify production capabilities to TT, firms relied on the skill sets of their workforce to adapt and learn how to produce increasingly sophisticated and innovative TT products especially as new fibres, machinery and processing technologies were introduced (Christopherson, 2009; Kalafsky, 2007).

The decision to invest, time and finances, into the adaptation of products and processes to TT was influenced by the ownership of the firm at the time of entry and transition. Over a third of firms in the sample (15/40) are family-owned businesses (Appendix G); a business influenced and managed by a complex family network (Greene *et al.*, 2001; Sharma *et al.*, 1997). This network includes either members of the same family, potentially with multiple generations, or a small number of families (Sharma *et al.*, 1997). Firms claim this provided them with the financial strength and long-term vision to decide to enter TT:

> *"The businesses that have survived have been the family businesses because they can take that sort of long-term view and largely they've got working shareholders in them. If we were trying to operate here with somebody running the business as a professional manager and me just sitting at home thinking I'll have my income thank you, it wouldn't work, it works because it's hands on… and you know you can take a view and say right well we're going to spend a bit of money or we're going to do this, and because we're doing that, we're probably not going to be able to pay any dividends for the next three or four years but we think that the money is better off being sunk into this"* (E-S-Weaver-6, 2013).

Family businesses have a strategic long-term perspective in their decision-making, with 'the desire to perpetuate their business and to pass it on to future generations' (Siebels and zu Knyphausen‐Aufseß, 2012: 289). These firms generally have the autonomy to decide where financial investments will be directed in the firm (Sharma *et al.*, 1997). In the case of adapting to TT markets, firms invested in new textile technologies as they became available.

The degree of adaptation to TT varies between the firms interviewed in the same sector (Table 4.8). This is because a firm's path dependency is idiosyncratic and determines their capacity to adapt in a particular space and time (Boschma and Lambooy, 1999; Martin and

Sunley, 2006). This section has emphasises how UK firms adapted their resources and capabilities to engage in the manufacturing of TT. Firm-based adaptation has required the development and employment of specific capabilities, these include financial strength to invest in new equipment, a highly skilled workforce to process new products on new machinery, as well as the company's owners and a management team willing to employ adaptation processes. Further research is required on whether these TT firms are different to firms who did not manage to transform themselves into producers of TT and have ceased to operate (DRA, 2001; Martin, 2010). Previous sections of this chapter have emphasised how changing competitive dynamics, the emergence of a new sector, technological changes and new products in UK firms external economic environments, resulted in a group of firms to respond in the twentieth century and engage in the adaptation to TT. The next section returns to the twenty-first century to examine UK TT firm's current external economic environment, in particular it investigates any existing pressures that would require the evolution or further adaptation of firm's routines.

4.6 Technical Textile External Economic Environment: Competition Changes

A firm's external economic environment includes the *economic climate* (policy, infrastructure and market conditions) of its own location of business activity, as well as the place of its customers, their *economic relationships* with competitors, suppliers and customers, and *market changes*, which include technological changes, new products and new types of competitors (E-RBV framework). Ever-shifting business environments and external pressures demand firms to respond via adaptation, to survive the pressures

confronted, as well as thrive in new market conditions and competitive dynamics (Martin, 2010; Martin and Sunley, 2010). The combined external pressures of changing competition dynamics and emerging technologies between the 1940s and 1990s, for firms that were associated to the traditional textiles industry, was especially formative in promoting the industrial evolution of the UK textiles industry (Martin, 2010). Competition is driven by innovation of new products, technologies and processes (Boschma and Frenken, 2006), and firms responded to changes in their competitive dynamics by adaptation and radical innovation in textiles to TT. This adaptation to a new industrial sub-sector of textiles changed these firm's competitive dynamics. The UK TT sector is now in competition with other sectors and firms in this new territory (Schamp, 2010).

UK TT firm's competitors are other TT fabric producers in the same market place, targeting the same customers. The type and intensity of competition depends on the market firms are operating in. Firms have identified a small number of key competitors, an average of 2.8 direct competitors that they regularly *"come up against"* in the same markets (E-S-[Narrow]Weaver/Knitter-2). UK TT firm's competitors are located in the UK, western Europe and the USA, which is where firm's key markets are located (Section 4.2) (Byrne, 2000). There are two explanations for UK TT firm's low number of direct competitors. First, the position of UK firms as a component supplier in the TT supply chain means they are locked-in with existing clients, and infrequently 'produce for end product markets', so they rarely 'find themselves in direct competition in end markets' (Christopherson and Clark, 2007: 62).

Second, UK TT firms are operating in niche markets and fulfilling particular gaps in applications with their ownership specific capabilities of specialist skills, machinery, production process type and products (Section 4.2) (Alliance, 2015; Bryson *et al.*, 2008; Teece *et al.*, 1997). UK TT firms do not regularly *"cross paths"* or experience competition from other UK TT firms (E-M-[Narrow]Weaver-1), and have limited competition from firms located in Europe, as most operate in their own niche markets for their products (Alliance, 2015):

> *"If you look within the UK at textile companies, we all cover different areas, I think because TT is so massive, that we just try, we're all doing different things within those markets, there's very few products that we do that are similar…. for us it's about doing something really novel that nobody else is doing"* (E-M-Weaver/Knitter/Nonwoven-1, 2013).

Firms have become specialists and experts in their chosen niche market, as they *"aim to be the leading innovator and supplier in* [a particular] *segment of a sector"* (E-M-Weaver-10, 2013), which is exemplified by the production of an airframe. Depending on their particular type of manufacturing process, companies supply specific textile components to the UK aerospace market:

- Aircraft seating (N-M-Nonwoven-2),
- Curtains and interior surface finishes including dado and side wall fabric and composites (E-M-Weaver-8),
- Seatbelts (E-M-[Narrow]Weaver-4),
- Reinforcements in pressure seal of the aircraft doors (E-S-Knitter-5),
- Ejector seats (E-M-[Narrow]Weaver-7),
- Composites for airframe, wing, doors, flooring, luggage lockers (N-M-Weaver-1, E-M-Weaver-7),
- Engine containment system (E-M-[Narrow]Weaver-1), and
- Electronic shielding and thermal protection composites (E-M-Nonwoven-3).

Operating in niche markets has determined UK TT firm's competitiveness, as one firm states: *"…I think the reason we've survived as a manufacturer in the UK, is that we haven't gone for volume business, we've gone for niche business"* (N-M-Weaver-4, 2013). Niche markets provide firms with distinctiveness and inimitability, making it more difficult for other firms to catch up or copy (Barney, 1991; Bryson and Taylor, 2010; Wernerfelt, 1984).

Despite the low number of competitors in TT markets, in the past fifteen years UK TT firms have 'not proved entirely immune to the effects of… product and market maturity, and of growing global competition which are all too well known in the more traditional sectors of clothing and furnishing' (Byrne, 2000: 1). Low-cost competitors are 'catching up', Asia's textile industry is following a similar process to the UK in the 20th century and beginning to move up the value chain by producing TT products (Byrne, 2007). Product maturity or commoditization is the evolution process of a product, which becomes more standardised and routinized to produce, and as a result price-sensitive with subsequent low-profit margins (Klepper, 1996; Utterback and Abernathy, 1975). According to product cycle theory, the production location of mature and commodity products 'shifts from creative seed-beds and core cities, where product innovation first occurs, towards lower labour cost locations in more peripheral regions and countries' (Martin and Sunley, 2010: 75-76). The shift of TT products to low-cost locations is not a process led by UK TT firms, but reflects the ageing and replacement of products by new forms of high-tech and advanced TT.

Mature TT markets (automation, aviation, sport and leisure) have initiated the growth of firms located in low-cost locations producing TT products through the relocation of their high assembly processes towards the end of the twentieth century (Byrne, 2000). TT components began to be sourced from where end products were being manufactured, for example China and Indonesia (Dicken, 2011; Gereffi, 2005):

> *"When I joined this company twenty years ago, they only manufactured transparent fabrics for loud speakers… the average fabric metre was £1.50 to £2.50 and you needed huge volumes obviously. I could see that the manufacturing of loudspeakers and the systems was going to China, and they would* [then] *source their fabric requirements from the Far East, its logical and the fabrics were not high tech compared to what we do* [now]*"* (E-S-Knitter-7, 2013).

Off-shoring TT products to developing market economies initially occurred in low value products (coated fabrics; canvas goods; webbing), which have less technical and functional properties, for applications of tents, luggage and components of footwear (Byrne, 2007). However, developing economies rapidly adopted the latest materials and processing technologies in TT:

> *"The threat of competition from China has been there for a number of years but we're only just really beginning to see evidence of it, with the core yarn product, the x-ray detectable yarn, we have seen significant competition coming from China…* [and there is] *more copying of advanced medical solution products"* (N-M-Nonwoven-1, 2013).

The capabilities of firms located in developing market economies in producing advanced TT is already highlighted by India's nonwoven industry and Taiwan's 'composites manufacturing sector specialising in sports equipment' (Byrne, 2000: 19).

The majority of high value-added TT product innovations were first commercialised in the 1980s (McQuaid, 2005). For example, UK TT firms introduced key product innovations in the 1980s that transformed the automotive market, including the one-piece airbag (N-L-Weaver-5), three-dimensional car seat cover (N-S-Knitter-2) and acoustic solutions in headliners (E-L-Knitter-8) and vehicle exhausts (E-M-Knitter0-3). Several firms undertook patents on the invention of these products for exclusive production rights (Kogler, 2015). However, the patents were registered to the UK only, and as products have become standardised, firms have not renewed patents (Greenhalgh and Longland, 2005). This has increased the amount of competitors from low-cost locations undermining UK TT firms on price with their own invented, but now standardised, TT products (Byrne, 2007):

> *"There are other technical knitting companies now, we were the first* [invented the process and product] *and we have access to the patents, but there are now others that have sprung up and doing what we do, competing with us in the office seating market…* [the patents are] *not being protected, no one is doing the patent searches, nobody is prosecuting anybody, so these companies are just chancing their arm and getting away with it because nobody is there saying actually you can't do that we've got a patents…plus* [the patents] *are getting old, they only live for so long, different territories twenty to twenty-five years maybe"* (N-S-Knitter-2, 2013).

Patents are difficult to monitor and regulate as competitors 'design around' the criteria (Young and Berthold, 2013). It only takes a competitor to *"half change* [a product] *and* [they] *can get away with it because it's different"* (E-M-[Narrow]Weaver-7, 2013). Furthermore, to pursue a case of infringement of a patent, enforcement costs can be high and lack certainty in succeeding (Young and Berthold, 2013). Firms located in low-cost locations access or unravel the intellectual property of products by reverse engineering; 'the process by which competitors acquire competitor's products to disassemble them to create copies' (Bryson and Rusten, 2011: 42).

This section has explored how firms located in low-cost locations are increasingly producing standardised products either due to the imitation of standardised TT products or because the production systems of these products have relocated overseas (Byrne, 2007). For UK firms operating in a global marketplace and the growth of emerging markets with new technologies introduced new types of competition in TT, including price-based competition (Byrne, 2007). These new competitors located in low-cost locations became a threat, which UK TT firms responded to through a second period of adaptation, in order to maintain their competitiveness as TT manufacturers in the UK (Boschma and Frenken, 2006; Hoopes *et al.*, 2003; Martin, 2010). Significantly, this section reveals how there has been two periods of adaptation in the UK TT industry, which are both a response to changing competitive dynamics in firm's external economic environments (Martin, 2010). The first period was in the twentieth century, between the 1940s and 1990s, and revolves around the emergence and formation of the industry. The second period can be traced to early 2000s, which has witnessed a further adaptation of UK TT firms to maintain their competitive position in the industry. Further research is required of this second adaptation period to advance the understanding developed in this chapter of the UK TT industry, as well as examine the sources of firm-based competitiveness, which would further explain how UK TT firms currently have a low number of competitors.

4.7 UK Technical Textile Industry: E-RBV Framework

The E-RBV framework provides a theoretical foundation to study the adaptation and evolution of manufacturing firms (Section 2.6). This chapter has identified the following

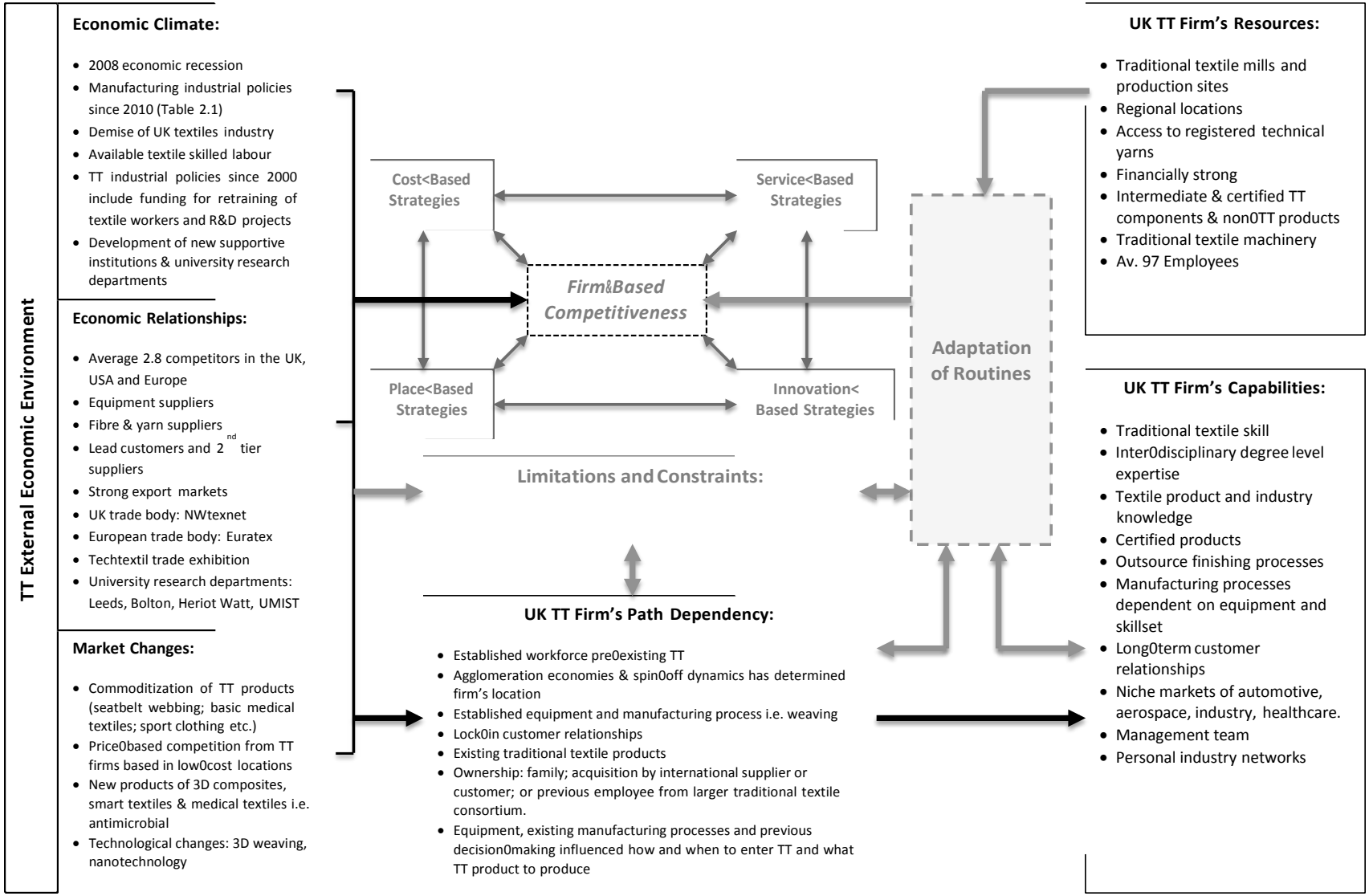
processes of the framework in context to the UK TT industry (Figure 4.9): resources, capabilities, path dependence characteristics and external economic environment. This chapter has modified the context of the original E-RBV framework in Chapter 2 (Figure 2.5), it has begun to identify firm-specific resources and capabilities of the UK TT industry, as well as pinpointing firm's economic relationships with competitors, suppliers, customers and institutions (Figure 4.9). An examination into the attributes and historical evolution of the UK TT industry has identified various path dependency characteristics of the TT firms, which are connected to the traditional textile industry:

1. UK TT firm's workforces consist of traditional textile employees with craft-based specialist knowledge, experience and skill level.
2. UK TT firms are located in the former 'textiles industrial heartland' of the UK due to path-dependent processes of agglomeration economies (Alliance, 2015; Boschma and Wenting, 2007).
3. UK TT firms have existing textile equipment and capital, which has determined their manufacturing processes, for example weaving or knitting.
4. Established long-term customer relationships determines the product portfolio of UK TT firms, as 35 per cent (14/40) of the firms interviewed are still providing a proportion of conventional textiles. However, these relationships have also driven firms to begin manufacturing TT and develop their capabilities in TT further.
5. The previous decision-making made by owners and management teams of UK TT firms has influenced firm's TT product and market portfolio. For example, the previous owner of E-M-Nonwoven-7 changed the firm's manufacturing processing operations from weaving to nonwoven techniques in the 1960s to enter the TT filtration market.

The previous section returned to the twenty-first century of the UK TT industry, to further understand the key attributes of UK TT firms. The external economic environment of firms

was explored, which revealed there have been key market changes for UK TT firms in the twenty-first century, especially the commoditization of mature TT products and changing competitive dynamics with new types of competitors (Figure 4.9). This highlighted that the sources of competitiveness developed by UK TT firms that has maintained their manufacturing systems in a high-cost location needs to be examined.

Figure 4.9: Technical Textile E-RBV Framework: Resources, Capabilities, Path Dependency & External Environment



4.8 Summary

This chapter has identified the key characteristics of UK TT firms in the twenty-first century, providing the first study and understanding of the UK TT industry in the social sciences. The history and formation of these firms was investigated, specifically the adaptation of firms to enter into the manufacturing of TT in the twentieth century. This research therefore contributes a detailed analysis on the evolution of an industry, the UK TT industry, which involved crossing over from an existing product (textiles) into a new product type (TT) and blending old machines (weaving looms) with new processes (3D weaving). TT products are so different to traditional textile products that in effect the UK TT industry is a new and emerging industry.

The adaptation to TT was not a uniform process, as it was based on the adaptability of firms, which is influenced by their individual path trajectories, as well as the decision-making made by firms over many different years (precisely between the 1940s and 1990s). It is noteworthy that this chapter has highlighted a significant contradiction to previous studies, which have emphasised how the emergence of a new industry is shaped by support institutions (Boschma and Frenken, 2009). The formation of the UK TT industry has been determined by firm-based adaptation and was actually autonomous to the support initiatives of industrial bodies (Section 4.4). This chapter confirms that the emergence and evolution of a new industry is driven by the micro-behaviour of firms, in response to alterations in customer behaviour and demand, and

changing competitive dynamics. In particular, this chapter explains how new forms of micro-behaviour are instigated by the interaction of path dependence and path creation (Boschma and Martin, 2007; Martin, 2010). This is confirmed by the fact that 77.5 per cent (31/40) of the firms adapted to the manufacture of TT from a traditional textile background, with a further 17.5 per cent (7/40) established as TT firms by former employees of traditional textile consortiums (Section 4.3). Path-dependent processes of UK TT firms, which included experience, knowledge and established manufacturing processing techniques, was combined with several new technological developments in textiles since the 1930s, to inform the adaptation of firms to TT.

Two periods of adaptation in the UK TT industry, in response to changing competitive dynamics, has been identified (Martin, 2010). The first period of adaptation was the transformation of firms to TT in the twentieth century, whereas the second period has occurred in the twenty-first century and revolves around the attempt to develop inimitable competitiveness strategies. The remainder of this thesis will focus on the second period of adaptation, in particular the last ten years. A focus on UK TT firm's recent adaptation is constructed from the evidence base that was accessible to the researcher during the data collection. The next chapter examines the firm-based competitiveness strategies developed by UK TT firms to maintain their manufacturing systems in the UK.

5 WEAVING COMPETITIVENESS: INTERWOVEN FIRM-BASED STRATEGIES

5.1 Introduction

The adaptation of textile manufacturing firms, as well as merchants, former textile employees and non-textile producers, between the 1940s and 1990s, was formative to the emergence of the UK TT industry (Boschma and Martin, 2007). This is the first adaptation period of the UK TT industry. The previous chapter examined this first adaptation period, which involved firms gradually developing and reallocating their resources and capabilities to enter into the manufacturing of TT (Chakravarthy, 1982; Hassink, 2007). Chapter four also identified the key characteristics of the UK TT industry, which identified a second adaptation period of UK TT firms that can be traced to the early 2000s (Section 4.6). This second period has involved the adaptation of UK TT firms, in response to the commoditization of TT products and new TT competitors located in low-cost locations (Byrne, 2007; Martin, 2010). To thrive in these changing competitive dynamics and maintain their manufacturing systems in a high-cost location, the second adaptation period of UK TT firms has involved the development of inimitable competitiveness strategies (Hoopes *et al.*, 2003).

This chapter explores the sources of UK TT firm's competitiveness. Chapter two identified how the nature and processes of firm-based competitiveness are non-linear and based on interwoven strategies (Figure 2.3) (Bryson *et al.*, 2013). Firms blend and combine four main competitiveness strategies in different ways to develop inimitability (Bryson and Taylor, 2010; Hoopes *et al.*, 2003). This involves a blend of cost-based competitiveness with non-price-based strategies, which are related to place, innovation and services (Bryson and Rusten, 2011; Mulhall and Bryson, 2013). An examination into the sources of firm-based competitiveness consequently presents a complexity in the analysis. It is difficult to isolate and focus on any one competitive strategy as each strategy influences an aspect and the development of another strategy.

This chapter therefore adopts a similar holistic structure to Section 2.4. It is divided into six main sections. The following four sections are interdependent as they examine the sources of UK TT firm-based competitiveness within each main strategy related to cost, place, innovation and service. The fifth section integrates all four competitiveness strategies discussed in this chapter to examine their interwoven aspects, which produce firm-based and inimitable forms of competitiveness. The sixth and final section provides a final summary to this chapter.

5.2 Cost-Based Competitiveness: Balanced and Lean

Cost-based competitiveness, the appropriate cost control and stripping of production costs, is critical for firms manufacturing in a higher cost base location (Bryson and Ronayne, 2014; Bryson *et al.*, 2008). Cost management enables TT firms to respond and adapt to changing cost structures and maintain their profit levels to be able to afford to manufacture in the UK (Mulhall and Bryson, 2013):

> *"It's about maintaining profitability, some of it's about making profits to invest in all this new equipment, which we see as the way forward"* (N-M-Weaver-1, 2012).

Profit is important to direct investment into the firm for long-term growth and to stay ahead of the competition (Mulhall, 2015; Rugman and Verbeke, 2002). The injection of financial capital provides firms with the capacity to adapt their current routines (Boschma and Frenken, 2006; Boschma and Lambooy, 1999). As highlighted by the above firm, which utilises profit to purchase new machinery to sustain their evolving path in TT by adopting the latest technological developments (Martin, 2010).

The location of UK TT firms is path-dependent to the historic evolution of the UK textile industry and local workforce, which is spatially immobile (Section 4.2) (Boschma and Wenting, 2007; Martin and Sunley, 2010; Storper and Walker, 1983). Geography determines the significance of cost management for firms, as the cost of factor inputs, for example labour, differs between locations (Walcott, 2011). Input costs are a key issue for UK TT firms as they claim to *"always* [be] *conscious of costs"* (N-S-Knitter-2,

2013). The main input costs for UK TT firms include localised costs of labour, utility and taxation, as well as non-localised costs of raw materials and equipment (Table 5.1).

Table 5.1: UK Technical Textile Firm's Input Costs

Localised Costs to High-Cost Location
Labour Costs: The labour intensity of manufacturing TT depends on the manufacturing process. Weaving is slower and more labour intensive because it is craft-based rather than knitting or nonwoven processes, which are more automated (E-M-Weaver/Nonwoven-2) (Sayce *et al.*, 2007; Walcott, 2011). Still, 70 per cent (28/40) of firms state their cost structure is always going to be an issue due to labour costs (E-M-Weaver-9). Further costs associated to labour include wage inflation, benefits, holidays, training, insurance and health and safety. **Utility Costs:** Utility costs include running costs of electric, gas, and water, as well as hidden costs in building maintenance and insurance as a lot of the UK TT factories are over 100 years old (E-M-Nonwoven-7, 2013). Firms claim, *"one of the shackles around manufacturing textiles here in the UK is the cost of utilities"* (Interviewee 1, E-L-Knitter-8, 2013), especially as utility costs are critical to the production of textiles: *"we spend about £10,000 a month for seven months of the year on heating bills to heat this place and that's not just the people but you have to keep the machines warm"* (E-M-Bobbinet-1, 2013). **Taxation & Duties:** Operating to European standards and meeting government legislation requires UK TT firms to pay taxes and duties, specific to operating in the UK and Europe: *"There's an anti-dumping tax duty on glass fibre from China, so we pay 13.8 per cent anti-dumping duty when we import glass fibre from China, but a Chinese fabric manufacturer doesn't pay any duty when they export it to the UK, so we pay a duty on the raw material but our customers don't pay any duty on the fabric… so you can buy fabric [in China] at the same price we can buy glass fibre"* (N-M-Nonwoven-2, 2013). This example explains how UK TT firms have additional operating costs which positions them at a cost and price disadvantage to low-cost competitors.
Non-Localised Costs in Global Marketplace
Raw Material Costs: Raw materials for manufacturing TT (high performance fibres) are significantly more expensive than non-technical fibres, for example cotton or nylon (E-S-Weaver-6, 2013). Firm's raw materials are predominately sourced from outside the UK: *"90 per cent is purchased in Euros"* (E-M-Nonwoven-7, 2013). Firms experience fluctuations in raw material prices from the global market and the currency exchange rate. Firms have to internalise any rise in raw material costs, as they *"can't pass it on [to customers], and a lot of tenders* [with their customers is] *a three year contract at a fixed price"* (E-M-Nonwoven-7, 2013). **Equipment Costs:** The production of TT is capital intensive and equipment is central to firm's capabilities of what type of TT they can produce (E-M-[Narrow]Weaver-3). The *"equipment to make* [TT products] *require significant capital and investment"* by firms (E-M-Weaver-11, 2013) as equipment requires maintenance, part replacements and modifications. Firms also have *"to continually replace and overhaul equipment as new technology comes into the market place"* (Interviewee 1, E-L-Knitter-8, 2013). The cost of new equipment is expensive ranging between £80,000 for a weaving loom (E-M-Weaver/Nonwoven-1, 2013) to £500,000 for a large warp-knitting machine (E-S-Weaver/Knitter-1).

Source: Interview Data (2012-2013)

All TT firms experience non-localised international costs, as suppliers of raw materials and equipment are in the global market place, which is regulated by market forces (Clark and Wrigley, 1995; Coe *et al.*, 2004). Localised costs are determined by local governance and market structures, which are specific to UK TT firms (Dicken and Malmberg, 2001). For example, UK TT firm's labour costs at the time of the interviews, were regulated by the national minimum wage of £6.19 in 2012 and £6.31 in 2013 for employees aged twenty-one and over (Table 5.2).

Table 5.2: National Minimum Wage in 2012 and 2013

YEAR	21 and Over	18 to 20	Under 18	Apprentice*
2012	£6.19	£4.98	£3.68	£2.65
2013	£6.31	£5.03	£3.72	£2.68

Source: GOV.UK (2015a)

*This rate is for apprentice's aged 16 to 18 and those 19 or over who are in their first year. All other apprentices are entitled to the national minimum wage for their age.

UK TT firms cannot control the price and cost of their factor inputs, which are set and regulated by governance structures of the national government and European Union, as well as market forces (Clark and Wrigley, 1995). However, they can manage these costs by controlling their own processing costs in producing a product, as:

> *"We can't set the price of the raw material and we can't set the price of our product because we don't live behind the iron curtain, the only thing we can do is concentrate on how much we have to spend in the middle and that's what our job is - to minimise the cost of turning that raw material into that product"* (N-M-Weaver-1, 2012).

To manage their production routine costs, UK TT firms are employing three cost-based strategies that have been identified from the interviews: balanced sourcing, consolidation and lean improvements. These strategies are examined next in the two following sub-sections.

5.2.1 Balanced Sourcing

'Balanced sourcing' is a concept used by trade bodies (NWtexnet) and firms to describe the development of a blended production system (Cusmano *et al.*, 2010; Tokatli, 2008). It involves the identification of labour intensive processes and outsourcing these production elements to low-cost locations, whilst retaining certain production activities in the UK (Hudson, 2010):

> *"We were employing probably 3000-4000 people here in the UK up until the year 2000, constructing those nets by hand, it's very difficult to mechanize and that's why we went to Sri Lanka,* [which] *is very much a textile manufacturing sector for the garment industry and so they had some skills there that were useful to us…"* (E-M-[Narrow]Weaver-6, 2013).

This firm and E-S-Nonwoven-6 both decided to establish manufacturing sites in Sri Lanka towards the end of the 1990s, to transfer labour intensive cargo palette net production and garment assembly from their UK sites. In these cases, balanced sourcing capitalised on place-based differential advantages of labour costs (Bryson, 2007; Dunning, 1998):

> *"…The transfer at that time was close to 30:1, so you could employ 30 people in Sri Lanka for the cost of 1 person in the UK and if you were talking of professional people such as engineers, then you would be looking at anywhere between 4-10*

> *people in Sri Lanka for the cost of 1 person in the UK"* (E-M-[Narrow]Weaver-6, 2013).

The Sri Lanka sites are wholly owned and under the management of the two UK firms, and operate identical quality systems and regulations of their UK sites, *"to maintain the quality and service but at an affordable cost"* (E-M-[Narrow]Weaver-6, 2013).

A second method to balanced sourcing employed by 40 per cent (16/40) of firms is to source labour-intensive, low value-added and high-volume commodity TT product ranges from companies located in low-cost locations (Cusmano *et al.*, 2010; Stratton and Warburton, 2003). For some basic TT products, it is cheaper to source and purchase from firms located in low-cost production locations than produce it themselves: *"Some webbings… were costing us 20p* [to produce] *when we can buy it in for 15p* [from China]*, it's a no brainer"* (E-M-[Narrow]Weaver-4, 2013). Balanced sourcing reduces firm's production costs, as it enables firms to keep their UK manufacturing sites at a relatively sustainable size, with less equipment and people. Firms do not have to employ a huge labour force and can 'flex' to customer orders, so when they receive a large order for high-volume products, they can sub-contract this and focus their UK operations on the production of high value-added TT products:

> *"If all my work overseas was manufactured here, I'd need another one hundred and thirty people… I'll let somebody else have the headache of employing the hundred* [people]*, we'll give them* [the contract company], *all of the components, they produce a good product, they get paid and if I need them next year or next week then yep great, and we'll expand and contract* [in size] *accordingly"* (E-S-Knitter-7, 2013).

Firms are acquiring some assets, for example labour, which they co-ordinate and control but do not have to financially invest, commit to or own by working with sub-contractors (Barney, 1991; Wernerfelt, 1984). A 'hybrid' model of *"so much* [production] *in the UK but* [also] *some external"* has provided firms with *"the potential to move* [their] *business to the market leader"* (Interviewee 1, E-L-Knitter-8, 2013), by focusing on high value-added and innovative TT production activities at their UK site (Section 5.4) (Hudson, 2010; Livesey, 2006). Balanced sourcing is associated to the process of consolidation and lean manufacturing, the next cost-based strategies examined, as firms have been able to reduce the size of their UK site with high value-added niche TT production (Dicken, 2011).

5.2.2 Consolidated and Lean Technical Textile Firms

The second cost-based strategy employed by UK TT firms is consolidation, which involves processes of M&As and downsizing. M&As were undertaken by 70 per cent (28/40) of UK TT firms. M&As have been opportunistic and arisen as traditional textile firms and TT firms have entered administration either due to overseas competition or retirement of current owners. The acquired companies have been absorbed by 82 per cent (23/28) of these firms into their own production sites (Appendix G):

> *"There's been probably about a dozen* [M&As]*… and they're all on this site now, it's far better, it's a lot easier, it's a lot more cost effective"* (E-M-[Narrow]Weaver-7, 2013).

This company has acquired other firms since the 1990s, to absorb further skill sets and equipment, and to develop their capabilities in additional textile manufacturing processes, for example sewing operations and transfer printing (Wernerfelt, 1984). All of the acquisitions by this firm have been moved into their one UK production site, which has increased the efficiency, resources and capabilities of the firm without creating additional productive capacity or costs (Bryson *et al.*, 2008).

The third cost-based strategy UK TT firms have employed is lean and agile manufacturing approaches, as it enables firms to do *"more with less,* [and] *that's how* [they] *stay competitive"* (Interviewee 2, E-L-Knitter-8, 2013). First, firms critically assessed their product portfolio to decide what products they could produce competitively in the UK, as *"bringing in cheaper products from another country does not fill our manufacturing guys boots"* (E-M-Nonwoven-7, 2013). They have removed some product lines that were not cost competitive to produce in the UK or could not be differentiated using non-price-based strategies:

> *"We've completely repositioned the business in the sense that we looked at a product, we calculated its cost, we calculated the margin that we wanted, if we could sell it at the market price, we kept it, if we couldn't we dumped it and it was as ruthless as that"* (E-M-Weaver-7, 2013).

Operating manufacturing activity in the UK utilises and retains a firms workforce, whose skill set determines the firm's adaptability to absorb new technological developments (Boschma and Lambooy, 1999; Martin, 2010). As Christopherson (2011:

4) contends 'if you lose manufacturing capacity, you risk losing the capacity to innovate'.

To retain their manufacturing activities long-term, firms had to ensure they were operating production at high capacity in the UK first before sub-contracting production (Section 5.2.1). Firms re-organised their existing manufacturing systems to produce more output, improve the quality of their production systems and reduce waste or rejection of products (Bair and Gereffi, 2003; Pavlínek and Ženka, 2010b):

> *"We've optimised certain processes and on relatively ordinary MOD webbings we're as cheap as anybody because we've got the processes under control, we've eliminated the waste, we've optimised the repeatability, we've optimised the efficiency in terms of time through the product, so as a result we can be extremely good value"* (E-M-[Narrow]Weaver-1, 2013).

The above firm explains how they have managed to reduce and control their input costs through efficiency improvements in their production process (Inman *et al.*, 2011). The implementation of lean manufacturing techniques has resulted in increasing productivity and manufacturing output with less production space and a smaller workforce (Hudson, 2010):

> *"We have to strive for lean manufacturing, with as little waste as possible and cost control. All those parts have led to massive reductions in people, painful,* [but] *necessary to survive"* (E-M-Weaver-11, 2013).

To manage their labour input costs, firms made redundancies in the 1990s [E-M-Weaver-9] and during the 2008 economic recession due to financial difficulties (E-S-Knitter-5). Labour is a recurrent expense but necessary input cost for UK TT firms

(Table 5.1). Enhancing the capital intensity of their manufacturing systems by automating labour intensive processes, has enabled firms to *"do it a little bit faster, and lower labour costs"* [E-M-Nonwoven-7, 2013). UK TT firms production processes are no longer labour intensive, and the requirement for a large operative workforce has been lowered with automation (Hansen *et al.*, 2013), as "*new machinery kind of de-skilled* [the workforce]*"* and *"it's less manually intensive than it would have been sort of twenty years ago"* (E-M-Weaver-8, 2013). The skill set of UK TT firms has changed, their workforce nowadays consists of highly skilled employees engaged and focused on value-added and sophisticated processes (section 4.2) (Christopherson, 2011; Hudson, 2010; Kalafsky, 2007, 2008).

UK TT firms have developed integrated cost-based competitiveness strategies, which are determinative in enabling the firms to afford to maintain their manufacturing systems in a high-cost location (Mulhall and Bryson, 2013). Each strategy provides a benefit of reducing production costs, increasing productivity, whilst improving firms individual capabilities and ensuring they dedicate their resources and time to the production of high value-added TT products (Table 5.3). Significantly, cost-based strategies cannot be pursued in isolation because they do not provide firms with inimitability; they can be easily copied either by firms located in low-cost locations with labour intensive production routines or via firms located in high-cost locations with capital intensive strategies (Barney, 1991; Bryson and Taylor, 2010). Cost control mechanisms need to be blended with non-price-based strategies of place-, innovation-

and service-based competitiveness that intend to develop product differentiation for TT manufacturing to continue in the UK, which are examined in the remainder of this chapter (Bryson *et al.*, 2013; Hoopes *et al.*, 2003).

Table 5.3: UK Technical Textile Firms Cost-Based Strategies

Strategy	Summary of Strategy	Cost-Benefit
Balanced Sourcing	Produce or source labour intensive low value-added, high-volume commodity TT products from companies located in low-cost locations and focus UK operations on the production of high value-added TT products.	This strategy preserves firms manufacturing sites to a sustainable size, but enables them to 'flex' their size or production capacity to customer orders, without the need to employ additional labour or invest in a high amount of capital.
Consolidation	The merger with or acquisition of other firms, which results in the firm sharing capabilities with the affiliated firm or absorbing the resources and capabilities of the acquired firm(s) into their own production site.	This strategy enables firms to acquire or absorb new resources (equipment) and develops their capabilities (skill set and knowledge), which increases the efficiency and performance of the firm without creating additional productive capacity or costs.
Lean Manufacturing	Increase the efficiency of manufacturing processes by improvement strategies, re-organisation of operations and automation of labour intensive capital production tasks.	This strategy enables firms to operate production at a high capacity in the UK and increase their manufacturing output with less production space and a smaller workforce. Automation enables a smaller workforce to focus on value-added and sophisticated processes.

Source: Interview Data (2012-2013)

This section has emphasised how the geography of UK TT firms determines the cost base of their manufacturing activities, in which firms have to respond to and develop cost management strategies. However, the location of firms can also be used to their advantage, by developing place-based strategies that require customer-firm proximity and cannot be obtained from another location, as they are dependent on locational resources and capabilities (Bryson *et al.*, 2008). The next section examines the place-based strategies employed by UK TT firms.

5.3 Place-Based Competitiveness: Logistical and 'Sticky' Strategies

Manufacturing firms based in the UK, a high-cost production location utilise their locally proximate resources and capabilities to develop non-price-based strategies (Bryson and Taylor, 2010). This emphasises the continued importance and competitive advantages situated within a firms local geography, whilst operating in a global economy (Hudson, 2010; Schroeder *et al.*, 2002). Place-based competitiveness is the development of strategies that revolve around the local geographies of the firm (Section 2.4.2). UK TT firm's local geographies have a number of dimensions, as they work with a variation of customers in far-reaching international markets (Section 4.2). Firms work closely with their customers for the co-production of products. They design and develop TT components to a particular customer specification, for the component to fit within a particular assembled end product (Alliance, 2015; DRA, 2001). The development process of TT products involves co-innovation, which is driven by

complex interactions and requires close proximity between the firm and their customer for regular dialogue (Bryson and Rusten, 2011; Loch *et al.*, 2007).

UK TT firms have developed two locational sources of competitiveness. First, firms are competing on logistical strategies of managing their interactions and linkages with customers located in different places (EEF, 2014; Foresight, 2013). Second, firms are competing on the basis of expertise (Bryson *et al.*, 2008), which is difficult to replicate by competitors (Bryson and Taylor, 2010). Labour is immobile and 'sticky' to the exact geography of the firm and therefore cannot be obtained from or transferred to another location (Christopherson and Clark, 2007; Storper and Walker, 1983). This section will examine both of these place-based competitiveness strategies in turn.

5.3.1 Competing on Logistics: Customer Proximity and Interaction

Logistical strategies are a key source of competitiveness for 90 per cent (36/40) of UK TT firms. Competing on logistics involves coordinating fast delivery turnover of low volume products and managing client relationships for co-production of products (Bryson and Taylor, 2010). These strategies are interlinked to service-based competitiveness (Section 5.5) as a form of customer service, which differentiates the firms from low-cost competitors (Hoopes *et al.*, 2003). The first strategy revolves around responsiveness of the firm to react quickly to customer orders:

> *"We had an order which was 278,000 metres and we dyed it, printed it, reeled it and dispatched it in ten days, you can't do that from China, that's the difference, it's either on a ship for weeks or it's on a plane at high expense so we can do that, we can react"* (E-M-Weaver-9, 2013).

Competitors located in Asia cannot physically offer the same level of responsiveness due to their geography (Bryson and Taylor, 2010; EEF, 2014). Proximity to key markets in Europe (Section 4.2) provides UK TT firms with a competitive advantage to achieve speed of delivery with special runs of low batch orders over their low-cost competitors (Bryson *et al.*, 2008).

Firms located in low-cost locations are organised to manufacture to maximum capacity and produce high volume orders for cost efficiencies and reductions (Dicken, 2007). Several TT customers, especially SMEs, do not require or cannot process high volume orders, nor do they have the financial resources to purchase in 'bulk' (E-M-[Narrow]Weaver-5) and therefore require local suppliers (Abernathy *et al.*, 2006):

> *"A lot of our customers don't want to be buying container loads of product and they can't afford to, they haven't got the storage space. So where we benefit, and China and Romania don't, is the fact that, within the UK especially, if one of our customers up in Nottingham wants three pallets of webbing, he can have three pallets of webbing, he isn't having to buy three container loads and store them somewhere because eventually it's going to cost him more, even though he's buying it per metre cheaper* [from China]*, by the time he's done the storage and his outlay initially it's going to be a lot more expensive for him"* (E-M-[Narrow]Weaver-4, 2013).

The capability of firms to offer very low or no minimum order thresholds highlights the distinctive locational competitive advantage of UK firms, as well as the competitive

disadvantage and weakness of firms located in low-cost locations (Bryson and Taylor, 2010; Foresight, 2013).

Low minimum orders by UK TT firms has become more important since the 2008 economic recession, as confidence amongst customers reduced and subsequently they condensed the size of their orders (Bryson *et al.*, 2013; Flatters and Willmott, 2009). Customers evaluated the quantity of products they needed to stock and invest in, and a lower cash flow meant they could not commit to a container load from low-cost locations (E-M-Knitter-4). This has led to a return of customers switching from a low-cost supplier to sourcing their production orders in the UK (EEF, 2014):

> *"The other good thing about the recession is it has made people who were buying from China, India, Sri Lanka and further afield from that, it's brought them back home again because they can't buy big volumes so even on standard stuff we've got old customers back because they want to buy smaller stuff, smaller amounts"* (E-M-[Narrow]Weaver-7, 2013).

This firm emphasises how the recent reshoring of manufacturing is associated with firms competitive advantages and localised geographies (Christopherson, 2013; Cowell and Provo, 2015). It may be cost advantageous to manufacture TT products in low-cost locations (Dicken, 2007). However, when the 'total' production costs are considered with transportation and delivery, UK TT firms are becoming increasingly cost competitive with local customers and markets (Gray *et al.*, 2013), as the following firm further explains:

> *"If you look at the physical constraints, the cost of shipping containers around the world has probably doubled or tripled in the last few years, so it is kind of*

> *swaying the balance, we've done a few projects where we could prove that it's cheaper now to manufacture here with us in the UK than to buy a container and ship it, I mean the unit cost of the product is more but the shipping costs and everything, when you add up the total costs it's a lot"* (E-S-Weaver/Knitter-1, 2013).

UK firms are employing logistical strategies with customers they have a close geographical proximity to, which differentiates them to low-cost competitors (Gereffi and Lee, 2012; Loch *et al.*, 2007).

Close proximity to key customers or to *"manufacture where they sell"* (E-M-Weaver-2, 2012) is a purposeful competitiveness strategy employed by UK TT firms. The establishment of new international manufacturing sites emphasises the significance of this strategy:

> *"China was set up in 2010, the strategy has never been about chasing low-cost wages, yes the wages are lower there but then so are all the firms we're competing with in China, because we're not exporting out of China, it's to supply a local market. So for us it's about following the supply chains that existed, Boeing, Airbus and Rolls Royce started going out there and making big chunks of aircraft. Our key customer went out there to start supplying pre-preg to their existing customers and here it's our part of the ship to either allow a supply chain to be developed in China to compete against us at some point in the future or to be part of that from the start"* (N-M-Weaver-1, 2012).

In this second period of adaptation, UK TT firms are witnessing their key customers, particularly in mature TT markets, relocating their production and assembly operations to China (Byrne, 2007). Between 2004 and 2010, 15 per cent (6/40) of UK TT firms "*mirrored"* their customers and built an additional manufacturing site in China, with another firm planning to have their site in operation by 2016 (N-L-Weaver-5). Firms

utilise their China site to service customers in the local geographical market of Asia, and retain the UK site to service customers located in the UK and Europe. This validates the increasing importance of place and co-location between suppliers and customers to produce products and deliver services (Bryson and Taylor, 2010; Gereffi and Lee, 2012).

The second logistical strategy UK TT firms have employed is the management of interactions and relationships with their clients. Markets for UK TT firms are primarily located in the UK and Europe (Section 4.2). TT firms have utilised the geographical proximity of the UK to Europe, and improved transportation links, to visit their customers. This enables firms to maintain and manage their client relationships by engaging in regular interaction and dialogue with all their customers located in different places:

> *"We try to visit every customer every couple of years, unless they're a big customer that we can visit quite easily say in Germany…* [Communication is very important]*, we spend a lot of time on the phone, but there's nothing better, the best thing is face to face meetings, the next thing is a telephone call because I always find customers are always prepared to tell you more when it's not down in writing or email, you can learn an awful lot by talking to customers"* (E-M-[Narrow]Weaver-3, 2013).

This firm emphasises the importance of regular interaction with clients and especially face-to-face communication. Client interaction enables firms to gain knowledge on their clients' changing markets and new technological developments for ensuing new or adapted product requirements (Asheim and Isaksen, 2002). Firms combine newly acquired market knowledge with their established client-based relationships, to build

upon and stimulate further product orders (Hansen and Birkinshaw, 2007; Laursen and Salter, 2006). Client relationship management and regular interaction therefore ensures firms continue to learn and avoid a 'lock-in' of their existing knowledge base (Boschma and Lambooy, 1999; Martin and Sunley, 2006).

This section has explored how UK TT firms are competing on logistical strategies, which are related to different local geography dimensions of different markets. For customers that firms have a close geographical proximity to, customers situated in the UK or Europe, firms have developed strategies related to flexibility of no minimum order, responsiveness and speed of delivery. UK TT firms have also developed locational sources of competitiveness related to client relationship management. This involves firms engaging in regular local-to-local firm-to-client interactions, predominately face-to-face communications, to facilitate expertise and innovative knowledge transfer on changing market expectations and technological developments. A focus on the E-RBV framework highlights that this section has also indicated how there are multiple local and global dimensions to UK TT firm's external economic environments, which are connected through the location of firm's clients and place of market. The next section examines UK TT firms second place-based competitiveness strategy, which revolves around the local geography of their production sites, by firms competing on their expertise capabilities (Christopherson and Clark, 2007; Storper and Walker, 1983).

5.3.2 'Sticky' Competitiveness: Skills, Expertise and Knowledge

The second place-based competitiveness strategy is the development of expertise capabilities, which are difficult to replicate or transfer (Bryson and Taylor, 2010). Labour and their inherent expertise are less mobile, spatially inflexible and difficult to move (Storper and Walker, 1983). This strategy builds upon firms distinctive capabilities, which combine existing expertise and relationships with clients to develop a source of competitiveness that is 'sticky' to the specific location of the firm (Christopherson and Clark, 2007). For cost-based competitiveness (Section 5.2), firms have reduced the size of their workforce through capital intensive and consolidation strategies (Hudson, 2010). However, during redundancy programmes firms have undertaken *"selective redundancy and kept the people with the right skills"* (E-S-Weaver-6, 2013). By combining selective redundancy methods with the employment of newly skilled textile and chemical technologists (Christopherson, 2009), firms have developed the *"highest skill set* [they've] *ever had"* (E-S-Knitter-5, 2013) (Section 4.2). UK TT firms rely on a technical and advanced skill base to produce sophisticated and challenging TT products, which can be difficult to produce (Christopherson, 2011; Kalafsky, 2008). The workforce of TT firms is not only critical for the successful operation of producing a TT, but are also associated with their competitiveness strategies.

The co-production of TT with customers, requires the capability of firms to understand customer requirements to develop a suitable and innovative TT solution (Hansen *et al.*, 2013):

> *"It's all about technical competence and knowing your products and being able to give the customer good advice about whether it's polyester or nylon that they should be using, and should it be a 38mm webbing… so it's not trying to sell double glazing, it really is about that long-term, working together* [and] *advice"* (Interviewee 1, E-M-[Narrow]Weaver-5, 2013).

Co-production therefore enables firms to demonstrate their specific technical knowledge and expertise in TT. The co-production process becomes a manufacturing experience of *"customer demonstration"* (E-S-Weaver-3), as firms *"typically invite people to come and visit"* their production sites *"to understand what's possible with a textile"* and for the firms to *"explain more with the examples in* [their meeting rooms]*"* (E-S-Weaver/Knitter-1, 2013). The demonstration of previous complex and innovative TT products to customers further supports the capabilities and expertise of firms:

> *"I suppose we have been lucky in the past that we've had probably the right technical developments at the right times, we've then been able to sell on our technical competence, so if we've already got an impressive level of technical competency that brings credibility and that gives us the ability to maybe guide and direct customers or at least be able to demonstrate we can do what their looking for"* (E-M-Weaver-8, 2013).

This firm explains how past TT developments enable firms to develop their credibility and reputation as an expert in the TT industry (N-M-Weaver-4). Firms expertise in TT products becomes a purposeful competitive weapon that differentiates the firm (Hoopes *et al.*, 2003; Rugman and Verbeke, 2002), as firms have *"all essentially got the same raw materials, the same equipment, so it's the brains"* (E-M-Weaver-2, 2012).

UK TT firms are competing on the basis of their expertise (Bryson *et al.*, 2008): *"You're not just selling your product, you're selling your knowledge and technical expertise that goes with that, and that's really where the added value comes in"* (E-M-Nonwoven-3, 2013). Firms have developed a complex blend of expertise to 'sell' and compete with. Five different types of expertise have been identified that are utilised by TT firms for the day-to-day running of the company, as well as combined to different sources of competitiveness (Table 5.4).

Table 5.4: Different Types of Expertise Utilised in Competitiveness Strategies

Occupation Position and Expertise Types	Description and Responsibilities
Production Expertise	• Yarn preparation • Setting up machinery and equipment • Machine operative of different production types • Inspection (by hand and automation) and mending • Problem-solving • Dye house and finishing processes
Operations Expertise	• Daily running of the factory • Forecasting and scheduling of production • Administration of customer orders • Warehouse stock of raw materials and supplier liaison • Delivery and distribution logistics • Quality control
Equipment Expertise	• Machinery and equipment maintenance • Machinery and equipment repair and re-build • Programming for setting up machinery
Technical Expertise	• Product research and development • Process innovation • Fabric analysis • Design • Product (quality and mechanical) testing
Customer Expertise	• Marketing (Inc. identifying new markets) • Sales • Customer services • Client interaction and relationship management • Specialist and technical market knowledge • Expatriate sales person for export markets • Foreign languages for communication to overseas customers

Source: Interview Data (2012-2013)

To exemplify Table 5.4, *operations expertise* enables firms to coordinate and manage delivery and distribution of their TT products for logistical competitiveness (Section 5.3.1) and *equipment expertise* allows firms to install new equipment for further automation as part of their lean manufacturing strategy (Section 5.2.2). *Production expertise* provides efficiency improvements to the firm as employees change production processes by daily assessment of *"how can we improve that? How could we reduce that down time? How could we increase the outputs without changing the inputs?"* (N-M-Weaver-1, 2012). These are all examples of how firms have combined different types of expertise to the competitiveness strategies currently reviewed in this chapter. Further examples of expertise blended with innovation- and service-based competitiveness strategies will be weaved into the remaining sections of this chapter.

5.4 Innovation-Based Competitiveness: Customised and Inimitable Solutions

Competition is driven by the arrival of new products and technologies to the marketplace and process improvements (Boschma and Frenken, 2006; Schumpeter, 1942):

> *"Most markets are driven by the desire for something new and something creative, something innovative, something that is different that keeps* [the] *customers ahead"* (E-M-Weaver-10, 2013).

Innovation first assisted firms to transform themselves into fabricators of TT, the first adaptation period (Chapter 4). In 2003 the firm E-S-Knitter-7 entered into the production of TT, of which *"every single product in* [their meeting] *room didn't exist,*

[they have] *had to take it from customer to prototype, to production, to where* [they] *are today"* (E-S-Knitter-7, 2013). For entry to TT, firms embraced technological developments in textiles and followed customer component requirements to innovate and develop new TT products (Braddock-Clarke, 2007a; Byrne, 2000). Innovation promoted diversification and evolution of the UK textile industry (Martin, 2010), as firms engaged in 'renewal' adaptation processes of learning and innovation to move up the value chain (Hassink, 2007; Livesey, 2006; Martin and Sunley, 2010).

Innovation has been the foundation of UK TT firms competitiveness strategies in the second adaptation period, as it has enabled firms to be responsive to changes in their external economic environment (Bryson and Taylor, 2010; Penrose, 1959). Firms are experiencing product maturity and subsequent growing price-based competition from companies located in low-cost locations (Section 4.6). In consideration of the fact that international competitors are chasing UK TT firms up the value chain at a greater speed (Byrne, 2007), the future of TT is dependent on the constant introduction of new products. The new currency in the industry is ideas (Day, 2012), as *"people are going to find* [firms] *products and copy them regardless,* [so] *it's how far* [UK TT firms] *stay ahead of the competition that is key"* (E-M-Nonwoven-3, 2013).

Firms need to ensure by the time rival companies have copied a product, they have introduced a stream of new, improved or redesigned products (Bryson and Taylor, 2010; Kakkad, 2009):

> *"China has been a bit of a challenge but it forces us to move on, in some ways it encourages you to look for new applications, develop new products"* (E-M-[Narrow]Weaver-3, 2013).

UK TT firm's innovation pipelines have to be maintained *"from performance advancement of* [their] *current materials to development of products for next generation technologies"* (E-M-Nonwoven-3, 2013). Firms *"need to advance and develop further their technical ability"* (Professor Horrocks, University of Bolton, Interview 2012) and compete with technologies, which won't be absorbed by low-cost manufacturers soon after (2BFUNTEX Workshop Field Notes, Croatia, 2012):

> *"So our kind of strategy of to keep ahead of the game is through kind of research and innovation, develop, develop, develop, keep ahead of the game as much as possible"* (E-M-Weaver-2, 2012).

UK TT firms are prioritising aggressive innovation strategies for continuous renewal of products and processes, and to become *"centres of excellence"* (E-M-Weaver/Knitter/Nonwoven-1; E-M-Knitter-3).

Continual innovation is required for UK TT firms to maintain their position in the market place, as well as their profitability from current product portfolios (Bryson and Taylor, 2010). The following two sub-sections examine the product and process sources of innovation-based competitiveness. These sections are interdependent as product and process innovation is related. For example, innovative products demand the development of sophisticated and flexible production processes for customised and co-produced products (Section 5.4.1). Equally, innovative production processes

allow technical products to be produced, as well as intricate process design and intellectual property rights to be built-in to products for inimitability (Section 5.4.2).

5.4.1 Innovative, Customised and Certified Products

Product innovation, R&D and science-based technological developments, is the archetypal innovation routine that maintain a firms position ahead of their competitors by introducing a constant stream of new products (Bunnell and Coe, 2001; Kakkad, 2009; Maskell and Malmberg, 1999b). UK TT firm's innovation routines have changed from speculative innovation, of designing products independent of customer demand and requirements, to co-innovation. Co-innovation provides firms with resilience to imitation (Bryson and Taylor, 2010), by developing products that meet the requirements of a specific application, 'rather than being technology-led by fibre and machine developments' (DRA, 2001: 33):

> *"Our drive has always been with closeness to market and driving the technical innovation through the market place with the end user and working closely with customers, so that then creates a need for if there are new fibres out there to consider those new fibres and their role that they can play within the products"* (E-M-Weaver-10, 2013).

A firms innovation routines are customer driven, which incorporates the needs of the customer in the product development process by either implementing 'user' or 'open' innovation processes (Bryson and Rusten, 2011).

User innovation is 'a process of product development by consumers and end-users, rather than producers and suppliers' (Bryson and Rusten, 2011: 194). Firm's ideas and their consumers needs are blended to produce new products: customers provide firms with their requirements for a textile fabric and *"in conjunction with a customer* [the firm will] *try and come up with a fabric that meets the bill"* (E-S-Weaver-6, 2013). Open innovation occurs when firms co-produce products with their customers as partners (Bryson and Rusten, 2011):

> *"Our technical people speak to Rolls Royce's technical people [and ask] 'where are you taking your products?' and 'where can we take our products to support where you're going?' So the investment in 3D weaving came from those kind of conversations with Rolls Royce,* [who] *were really interested in understanding how to incorporate 3D pre-forms into their engines and how it would improve their composite parts, so we've got another half a million pound investment in weaving technology which has no commercial outlet just yet, but for the last four years it's been working flat out on a technical project"* (N-M-Weaver-1, 2012).

Both user and open innovation processes transform TT firms into providers of service-enhanced products, driven by complex interactions between the producer and consumer (Bryson and Rusten, 2011; Bryson and Taylor, 2010). Products are customised as firms respond to client needs through the development of co-created textile solutions (Gebauer *et al.*, 2011; Loch *et al.*, 2007):

> *"*[We develop] *innovative solutions from all our members of staff, we provide a unique customer focus where every employee has an input into helping achieve our customer's requirements"* (E-S-Knitter-5, 2013).

This firm re-emphasises the significance of firms competing on their intangible expertise capabilities, to implement their innovation strategies of developing novel

textile solutions for their customers but in the context of cost control (Bryson *et al.*, 2008).

New customer requirements combined with new technological developments enable firms to cooperatively co-innovate as partners in a production project to develop new TT products (Bryson and Rusten, 2011). UK TT firms are third tier suppliers of fabric components (Section 4.2). Firm's product innovations are intermediate inputs into different customer innovation systems and wider production projects. Bryson and Rusten (2011) introduced the Production Project and Distributed Tasks (PPDT) approach to explain how the formation of products, which are intended to create value, consist of many different sub-tasks of design, manufacture and services. These distributed tasks link together in a production process through complex inter-relationships to form a product. A firm will consist of many different production projects with each project resulting in a product. One firm within a partnership of firms will control each production project, and coordinate the partner firms own sub-processes and tasks required to produce a product (Bryson and Rusten, 2011).

UK TT firms coordinate the tasks required to develop and produce a novel intermediate component for many different production projects. E-M-[Narrow]Weaver-7 supply key textile components for manufacturers of ejector seats in aerospace in one production project, as well as textile components to manufacturers of climbing harnesses in another. Table 5.5 outlines the product development process

UK TT firms undertake with their customers. Co-innovation is a collaborative process of many backward and forward linkages between the producer and consumer, as products are in a continual process of becoming (Bryson and Rusten, 2011). This also provides an example of how innovation processes can determine the co-evolution of firms and customers to sustain their competitiveness (Schroeder et al., 2002; Ter Wal and Boschma, 2011).

Table 5.5: UK Technical Textile Firms Product Development Process

1	Review Customer Application or Enquiry and Process Parameters
2	Identify performance goals, legislation, specific requirements of product
3	Select and formulate appropriate product specification
4	Develop and test product developed
5	Manufacturer prototype of product
6	Identify process modifications and system issues
7	Liaise with customer and conduct trials where necessary
8	Review performance of product
9	Refine, finalise and Supply Product
10	Install with on-going condition trending and reporting

Source: Adapted from E-M-Nonwoven-7 Company Brochure (2013)

UK TT firms have developed product capabilities based around certification (Bryson and Ronayne, 2014). A firms TT fabric is an intermediate product that can influence the overall performance of the final and complete product. Thus, 57.5 per cent (23/40) of

firms produce products that are independently certified to industry regulations of their customers markets:

> *"The air frames are fixed to the aircraft and restrain loads. They are structural to the aircraft, so they are as much part of the aircraft as the engines, the wings, the tail, they are certified as part of the aircraft… our products, we would describe as safety-critical, you only need our product to work once and you certainly hope that if that occasion arises, it works because if it doesn't, the plane does crash as was strongly suspected to be the case of the 747 crash in Bagram just recently, they're pretty sure that cargo shift changed the centre of gravity of the plane and it couldn't recover…"* (E-M-[Narrow]Weaver-6, 2013).

Product certification usually occurs in safety-critical industries such as aerospace, military, defence, safety harnesses and medical products.

Certification locks TT firms into supply chains that provides them with market security:

> *"… if you get your products certified as part of the aircraft you're on that aircraft for the next forty years, you don't change aircraft certifications very easily, it's a huge thing to change… once you sell to the aircraft manufacturer, the airlines have to come and buy from you pretty much, it's not quite that simple but it gives you a huge degree of security"* (E-M-[Narrow]Weaver-6, 2013).

Certified TT products can have a value-added lifecycle of over forty years, which provides some of the firms with a long-term and locked-in relationship with a customer (Gebauer *et al.*, 2011; Martin and Sunley, 2006). Accreditation can make it expensive for customers to identify a cheaper substitute, as any substitution would mean that the product and its production process would have to be reaccredited, which reflects the sunk costs a client invests in during the accreditation process (Clark and Wrigley, 1995, 1997):

> *"*[In the Personal Protective Equipment (PPE) industry]*, the whole kit* [a climbing harness has to be] *tested, not just our bit of webbing, if they want to save 5p on a bit of webbing, they've got to then retest that whole kit and spend tens of thousands of pounds getting it tested, so once you're in, you're in"* (E-M-[Narrow]Weaver-7, 2013).

A firm's intermediate position in the supply chains and certification of their TT components is a key source of innovation-based competitiveness. First, it provides protection from competitors, as TT components can be very small and inexpensive in relation to the overall product. Customers are therefore unlikely to switch suppliers to a cheaper low-cost competitor due to the cost-benefit disadvantage of reaccrediting the specification of a component. Second, an early and previous product innovation provides a firm with market stability: *"the activity is stable and as a result it gives* [firms] *a good base to make sure that the next business activity can be established and pushed forward so* [they're] *not looking over a cliff"* (E-M-[Narrow]Weaver-1).

However, certification could also result in a 'lock-out', or barriers, to developing other relationships with customers in the same market place. This is because most certified TT components have agreed NDAs between the firm and client, which stipulates that the firm can only produce a specific TT component for the particular customer that engaged in the process of co-innovation and co-production with the firm:

> *"Our normal terms of conditions with customers are, lets say we develop you a fabric for a new plastic cast we won't sell that particular fabric to anybody in the medical industry"* (E-S-Weaver/Knitter-1, 2013).

Firms therefore tend to *"*[work] *hand-in-glove with a customer to develop something…* [and] *work one fabric to one customer"* (E-S-Weaver-6, 2013). To prevent a negative

'lock-in', where customers limit a firm's innovation capabilities with certain textile technologies, firms are employing *"cross fertilisation"* strategies. This is where firms apply an innovation for one application into another application, *"from one industry to another, so* [where] *solving problems from one particular fabric, from one industry, might be applicable in something completely unrelated, in a different industry"* (N-S-Knitter-1, 2012). For example, N-S-Knitter-1 *"makes a heavy duty stretch fabric for the Special Forces that dive, to help with Deep Vein Thrombosis"*. They *"use exactly the same construction of fabric to provide a stretch panel in a power trapping project, which is a new thing that hasn't hit the market yet but basically* [they] *want to replace shrink wrap because 250,000 tonnes goes to landfill every year… so* [E-S-Knitter-1 are making] *a pallet sock…*[from] *the same fabric for the diving application, [they] stretch* [the fabric] *into this pallet wrapping product, which is an entirely different market but it's still the same filament fabric".*

This section has examined how product innovation has become a source of competitiveness for UK TT firms. Firms are introducing a constant stream of new products by working closely with customers and following their specific requirements. Co-innovation of a new TT component between the firm and their customer can lead to a product becoming certified to the production of an end product, for example an aircraft. Certification of a specific product 'locks' the firm to a particular customer, providing them with protection from other competitors. Firms *"use the knowledge of previous samples* [they've] *made"* (E-S-Weaver/Knitter-1, 2013) for a specific

production project to *"cross-fertilise"*, meaning to apply the knowledge and expertise developed with producing a product for one market to an unrelated market for further product innovation. Innovative TT components require sophisticated and flexible production processes to meet the demands of new product innovations, as well as the personalisation requirements of producing exclusive products for specific customers. The next section investigates the process sources of innovation-based competitiveness.

5.4.2 Inimitable Equipment and Production Processes

Process innovation involves the development of new, adapted and improved production processes and working practices (Dicken, 2011; EEF, 2013). It has enabled firms to upgrade their manufacturing processes to advanced and high value systems, which subsequently adds value to their products (Livesey, 2006). Process innovation mechanisms have permitted UK TT firms to improve their productivity, responsiveness and quality awareness for cost-based strategies (Section 5.2) (Humphrey and Schmitz, 2000; Inman *et al.*, 2011). The improvement of processes has supported firms logistical and innovation strategies, by the development of 'just-in-time' production systems for quick delivery of bespoke and customised orders (Section 5.3 and 5.4) (Bryson *et al.*, 2008).

Previous sections have emphasised how innovation is underpinning UK TT firms competitive strategies (Maskell and Malmberg, 1999b; Penrose, 1959; Schumpeter,

1942). Still, process innovation is increasingly becoming its own source of competitiveness (Bryson and Taylor, 2010; Loch *et al.*, 2007), as UK TT firms develop machine-based innovation strategies that provides them with an inimitable manufacturing process, which is difficult to replicate by competitors, to produce their own product innovations. Distinctive production processes enable UK firms to produce TT products with *"…design knowledge, something built-in to the material that competitors can't copy"* (E-M-Weaver/Nonwoven-1, 2013). Intricate process design is one inimitable mechanism for firms to manufacture intellectual property into their products (Bryson and Rusten, 2011; Young and Berthold, 2013).

The research process of this thesis was particularly difficult due to concerns over commercial sensitivity related to intellectual property rights (Saunders *et al.*, 2009). As a result, 45 per cent (18/40) of firms would not permit the researcher access to their shop floors (Section 3.3.3). UK TT firms use similar equipment depending on their production process type, yet firms are utilising their equipment to create inimitability (Barney, 1991). Machine-based innovation strategies are utilised by 52.5 per cent (21/40) of UK TT firms. These firms have implemented special *"proprietary"* additions or developed specific modifications to their machinery:

> *"What we've done is that everything underneath that line* [bottom half of the machine] *is a crochet knitting machine and they have been the same since I don't know 1823, they're really old technology however, everything above* [on top of the machine]*, that is what we've designed, it's our software, our control, our methods"* (Factory Tour, E-M-Knitter-3, 2013).

Equipment modifications provides firms with *"a sort of black box of technical knowledge"* (N-M-Weaver-4, 2013) to produce inimitable and exclusive products that cannot be replicated by their competitors (Bryson and Taylor, 2010):

> *"We've found a way of producing very narrow* [webbing]*, without it twisting, so almost like 8mm in width, but nobody can weave that,* [which is] *for* [harness] *slings,* [which are produced for the rock climbing industry]*"* (E-M-[Narrow]Weaver-7, 2013).

Bespoke equipment modifications can be developed in consultation with machinery manufacturers (De Jong and von Hippel, 2009):

> *"*[The 3D knitting machines] *were developed with the machine manufacturers, we got them on board and partnered with them, because we needed things on machines that didn't exist… we have the machines made to our specification…* [It's] *based on the standard knitting machine that's knitting sweaters worldwide,* [but] *we have some modifications for technical knitting, some things added, some things taken away, some things adapted… we've got a technical specification that we require so some of the parts that we have are only for us"* (N-S-Knitter-2, 2013).

Firms are exploiting *"the capability of their textile equipment"* (N-M-Weaver-1, 2013) with machinery suppliers, which often have design and technical expertise to assist firms in process improvements (Asheim and Isaksen, 2002; Kakkad, 2009). Alterations made by machinery manufacturers are concealed by NDAs to prevent equipment innovations being learnt by competitors (E-M-Knitter-4) (Bryson and Ronayne, 2014).

Equipment additions and modifications are considered commercially confidential; *"a trade secret"* (E-S-Weaver/Knitter-1, 2013) and firms are *"selective with who* [they]

work with" (E-M-Nonwoven-7, 2013). Increasingly, firms own engineers are modifying equipment additions themselves:

> *"We have an engineering room where we do our own engineering, we build pieces of the machines ourselves, we just buy the machine itself from Germany, and all the extra pieces we buy ourselves"* (N-M-Nonwoven-2, 2013).

Firms are purchasing machines but do not want their suppliers to *"… know what* [they are] *doing, so* [they] *might buy the kit, and then make modifications"* (E-M-Weaver/Knitter/Nonwoven-1, 2013). One firm notes that machinery modifications are *"all done in-house, you keep something like that to yourself otherwise everybody would be buying it* [from the machinery manufacturers]*"* (E-S-Weaver/Knitter-1, 2013). This exemplifies how UK TT firms 'are the typical developers of process equipment innovations' to serve their own product and process needs (De Jong and von Hippel, 2009: 1182). It also emphasises the importance of a TT firms workforce and expertise *"… not only* [to] *do the weaving* [or] *the servicing side,* [but to] *also rip a machine down and put it back together*" (E-M-[Narrow]Weaver-4, 2013).

This section has examined the process innovation sources of firm-based competitiveness. Process innovation is related to other competitive strategies of cost management to improve productivity of firm's production processes and flexibility for just-in-time production routines and logistical responsiveness. Process innovation is formative to UK TT firms product innovation capabilities, as it enables them to produce inimitable innovative products, with machine-based strategies. Machine-based innovation strategies involve firms building in design knowledge into the construction

of a particular product by equipment modifications and additions to their machinery. Therefore this provides UK TT firms with inimitable or difficult to replicate products, as well as manufacturing processes, for competitors attempting to copy a firm's product. The next section examines the competitiveness sources of the final firm-based competitive strategy related to services.

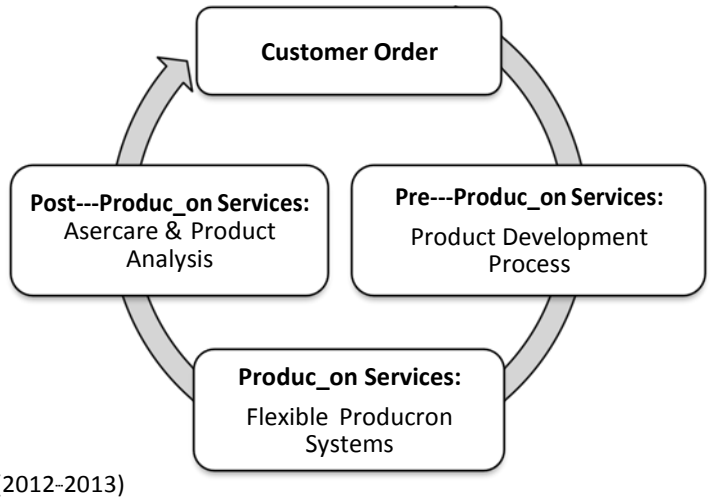
5.5 Service-Based Competitiveness: Credible Services and Relationships

Service expertise and processes are increasingly determining the economic value and competitiveness of manufacturing firms in developed market economies (Bryson and Taylor, 2010; Daniels and Bryson, 2002; Gebauer *et al.*, 2011; Loch *et al.*, 2007). Services provide firms with inimitability, as products with related services make each product an imperfect substitute for competing products and lock customers into longer-term relationships as captive clients (Barney, 1991; Gereffi *et al.*, 2005). UK TT firms supply bespoke and customised intermediate components into niche markets (Neely, 2007). This involves co-production activities between the producer and consumer as *"…each fabric produced is designed from scratch with the customer"* (N-S-Weaver/Knitter-1, 2013). The process of co-production and co-innovation has resulted in a blend of manufacturing, production and product-related services (Bryson *et al.*, 2004; Foresight, 2013). It is therefore noteworthy that firms are beginning to regard themselves to be *"more of a service business to direct textile users* [their customers]*"* and *"as a service industry* [they] *tend to be close to* [their] *market"* (E-S-Weaver-6, 2013). The inclusion of services into firm's production systems emphasises the

importance of close proximity to market, as some service elements have to be delivered locally (Section 5.3).

TT products are an example of a hybrid product, which contains the combination of manufacturing inputs for the product to be produced and function with embedded services (Bryson *et al.*, 2013). The embedded services are woven into the product so *"…when* [customers] *buy the product,* [they] *tend to buy all the services as well, so* [for example] *development services* [and] *regulatory support services*" (N-M-Nonwoven-1, 2013). These services cannot be separated from the product or purchased independently as this *"…offering is difficult to put into monetary terms"* (E-M-Knitter-3, 2013), especially because they have become critical elements in the production of the product (Neely, 2007) (Figure 5.1).

Figure 5.1: Embedded Services of Technical Textile Products



Source: Interview Data (2012-2013)

UK TT firms provide particular service inputs during co-production activities. There is a continuous service cycle that has three main phases of pre-production-, production- and post-production services (Figure 5.1). The service cycle begins with the concept of a specific customer order and servicing a customer before production with the product development process outlined in Table 5.5. The second phase, production related services, revolves around flexible manufacturing systems. The first production service is customisation, firms produce, test and certify a product to meet a specification agreed between the firm and their customer in phase one of a TT firms service package.

Customer-focused services of co-innovation and customisation emphasise the flexibility and adaptability of UK TT firms production systems to client needs. The adaptation of UK TT firm's production routines is investigated in Chapter 6. Second, logistical strategies are interlinked to production service strategies of adjusting delivery times and permitting low order thresholds (Section 5.3.1). To further explain this service provision, UK TT firms have *"…done emergency van deliveries and couriers by bike"* (E-M-Knitter-4) to *"…go out of* [their] *way to do things, which not a lot of* [their competitors] *are willing to do"* (E-M-Weaver/Knitter/Nonwoven-1, 2013). Firms will also hold stock for their customers till they require a further supply of TT products into their production projects so *"…if the order is 20,000 metres, we send 5000 out straight away and the other 15,000 we put into stock and then they call that off over the next couple of months"* (E-M-Weaver/Nonwoven-1, 2013).

Post-production services, the third phase of embedded services, include aftercare services and product improvements that are delivered during the ownership of product. Aftercare services include after-sales maintenance for the life of the product, by regular technical servicing by TT firms of their components (Bryson *et al.*, 2013; Neely, 2008):

> *"Our products provide a technical reinforcement to a customer's process… our technical team are often on* [the customer's] *site, and they've been running trials to check the rheology* [properties, or viscosity] *of the chemical reactions* [on a material]*, to check the unwind tensions, so we offer a sort of service of making sure our products fit inside a customer's process"* (E-M-Weaver-12, 2013).

Each TT component is custom-made to fit within a customer's product or process. Services are therefore inherent to the product, in terms of technical support to ensure the TT component is performing and meeting customers final requirements either in a final product or a whole process (E-M-Weaver-12). Firms perform mechanical testing, undertake any repairs on the TT component if necessary and assist in solving any technical issues for the customer (Neely, 2008). To assist the firms in delivering accurate technical support, they have employed engineers *"…that maybe used to work for* [their] *customers and are now working for* [them]*, that understand more about* [customer's machines and processes] *than they do about weaving machines"* (E-M-Weaver-2, 2012).

Additional post-production services include all forms of consultancy (Bryson *et al.*, 2013). UK TT firms undertake non-manufacturing capabilities in their production systems of product improvement analysis (N-M-Weaver-1):

> *"We also analyse* [TT] *fabrics that* have [been used as a component in a] *paper machine, so every* [TT] *that runs on a paper machine we try to get a sample back, so a full width sample [and] we analyse* [the fabric]… [to] *then feedback that information to the applications people who are deciding which design is the best for that particular customer, so he can learn something from that analysis which might help him make a better decision next time when we're talking to the customer* [of] *how to optimise and improve the design [of the TT fabric]"* (E-M-Weaver-2, 2012).

UK TT firms undertake a range of analytical tests on their TT components after they have been supplied to their customers and also once the product has become redundant. Product analysis assists the firm to develop their own knowledge and learning on textile and fabric performance (Cherif and Adolphe, 2009). This expands firm's expertise for future product developments, to advise customers on a better or improved performance solution:

> *"We're very keen on understanding, not just supplying product, but understanding what our customers are doing with it, so we can add some value by saying 'right, we're the experts about webbing, now we understand what you're trying to do, maybe you should be using this yarn not that one, or maybe you'll get a better result if we supplied you* [this type of] *product"* (Interviewee 1, E-M-[Narrow]Weaver-5, 2013).

Understanding clients' products and processes, as well as understanding how their TT components interact within it, has enabled firms to co-produce with their customers efficiently and stimulate further product orders (Hansen and Birkinshaw, 2007; Laursen and Salter, 2006). Firms also assist their customers with full market support,

undertaking gap analysis and market expectations, which again for the same reason, builds upon orders with their current client base for new product developments (Asheim and Isaksen, 2002).

UK TT firm's state their service-based competitiveness strategies outlined above, are *"areas* [they] *can differentiate* [themselves]*"* (E-M-Nonwoven-7, 2013). The development and execution of services are exclusive and distinct to each firm creating inimitability (Bryson and Taylor, 2010; Penrose, 1959). This is because services are dependent on intangible and specific capabilities of the firm, for example certain individuals. Equally, as each TT product is a tailored textile solution in response to customer enquiries (Heimbach, 2013), services are personalised to each customer as firms modify product configurations or service support to customer needs (EEF, 2014; Foresight, 2013).

This section has shown how TT is an example of a hybrid product, a blend of manufacturing inputs to produce the product with production and product-related services (Bryson *et al.*, 2013; Neely, 2007). The first embedded service involves the process of co-innovation and co-production of products with each client, the second service is flexible manufacturing systems to produce customised and personalised products and the third includes after-care services. After-care services comprise of after-sales maintenance, product improvement services, the performance testing of TT components, and full market support. This builds upon the previous section, which

discussed how firms become locked-in to a particular client base with certified products, firms stimulate further product orders and developments with existing clients by undertaking additional services of product gap analysis and market expectations. This section highlights how service-based strategies are related to place-based strategies, as the delivery of services requires close proximity to clients, and innovation-based strategies of employee capabilities to develop a novel TT solution, as well as the development of a flexible production system to produce personalised products. The next section examines the importance of supportive client relationships as a source of competitiveness, as well as a strategy to achieve the successful delivery of personalised hybrid products.

5.5.1 Supportive Client Relationships

Co-production and co-innovation enters UK TT firms into long-term contracts and establishes long-term relationships with consumers (Gebauer *et al.*, 2011; Neely, 2008). The establishment of close trust-based personal relationships with client companies has become a key source of competitiveness (Bryson and Ronayne, 2014). UK TT firms are operating in a very competitive market segment, and are producing similar products depending on their production capabilities, for example narrow fabrics. All of the firms stated that product orders are increasingly determined by personality and the quality of the long-term relationships that they have with their customers:

> *"To carry on differentiating yourself in this business, we go down the path of relationships… rather than the pure product itself, anyone in this industry if*

> *they're honest about it, the six or seven main competitors in this area, we all produce very similar product from very similar materials, we all have some individual products that we've got intellectual property on and we believe they are the bee's knees and they can give an advantage to a customer, but beyond that we're very big on having that relationship with the customer"* (E-M-Weaver-11, 2013).

Client relationships provide firms with inimitability, as each relationship between the producer and consumer is time and place specific and cannot be replicated by a competitor (Bryson and Taylor, 2010; Frenken and Boschma, 2007; Gebauer *et al.*, 2011).

UK TT firm's client relationships develop close bonds and over time individuals *"become friends"* (E-M-Nonwoven-7, 2013), forming personal relationships as one firm noted *"…one of the customers I've dealt with for many years… comes over and you want to go and play ten pin bowling and this, that and the other, it's a good relationship"* (E-M-[Narrow]Weaver-4, 3013). Once a relationship with a customer is established, it tends to last for the lifetime of the product (E-M-Weaver-12):

> *"We had a sales girl who worked here and move to E-M-[Narrow]Weaver-5… she tried to steal a lot of our business,* [but] *she said 'they just won't move from your company', whether it's me that's dealing with them or whatever they like dealing with this company… I think that is the difference because there is no other difference, I think it's personality led rather than product"* (E-M-[Narrow]Weaver-7, 2013).

This firm states how UK TT firms are increasingly competing on the basis of personnel and the culture of the company (Bryson and Taylor, 2010; Gebauer *et al.*, 2011). Strong long-term relationships form between firms and their clients as customers are

communicating with *"…the same person they have probably spoken to for the last twenty years"* (Interviewee 1, E-M-[Narrow]Weaver-5, 2013). The co-production of technical products is a partnership between producer and consumer, and requires more *"customer care"* (E-M-Bobbinet-1, 2013). Communication and how they conduct business with their customers, especially how they respond to any issues or problems, is critical to develop trust and loyalty amongst customers so they do not move towards a competitor (E-S-Nonwoven-6).

To build upon established relationships, TT firms have to develop a detailed understanding of their clients (TCSG, 2000). This is challenging for firms as they produce intermediate inputs (TT fabric) into many different applications (Section 4.2), and have to develop extensive knowledge on each market they operate in:

> *"We understand fire-fighters, we understand our market space in terms of what we do, we even participate in a process of going on shouts with fire brigades around the world so that we understand what it means to be that fireman, what it means to feel that kit* [the uniform]*, what it means to wear it, how it works, so we understand all that detail… and we're in 30-40 markets so we have to understand 30-40 markets in depth, which is really tough, so our biggest challenge is we've got to understand from the end user back to us and everything in between and understanding it completely"* (E-M-Weaver-10, 2013).

This firm describes how they have to extensively understand the needs and dynamics of many different end-users and market sectors. UK TT firms have to develop a broad basis of expertise on their own manufacturing processes, new technologies available for product innovation, as well as each client's requirements of the TT fabric in different production projects (E-M-Nonwoven-7).

Understanding their clients is so critical that some firms recruit consultants on certain markets and employees who used to work for end users. Firms recruit these industry specialists for *"… their knowledge on the industry, we can soon teach them about the product, it's their contacts and knowledge of the industry that's more important to us"* (E-M-[Narrow]Weaver-3, 2013). External knowledge learnt from customers strengthens firm's competitiveness and avoids lock-in (Asheim and Isaksen, 2002; Boschma and Lambooy, 1999).

This section has highlighted how client-based relationships between the UK TT firms and their customers are time and place specific, and determined by the culture of the firm, personalities of key individuals and the quality of these relationships. This explains how supportive client relationships are a key source of competitiveness, which cannot be replicated by a competitor. Client relationship management is essential to maintain or cement the strength of established relationships. Firms achieve this by first being supportive of their clients and responsive to any issues, and second by continually assessing and developing an extensive knowledge and understanding of the TT requirements and dynamics of their clients. Significantly, this section emphasises that UK TT firms are blending their expertise capabilities, locational advantages of proximity to customers and innovation-based strategies to develop and implement service-based competitiveness (Bryson and Taylor, 2010). The next section integrates all four competitiveness strategies outlined in this chapter and explores

their interwoven aspects, which provides UK TT firms with inimitable forms of competitiveness.

5.6 Firm-Based Competitiveness: Interwoven Strategies

Previous sections of this chapter have provided a detailed account of UK TT firm's sources of competitiveness within four strategies related to cost, place, innovation and services. Many of these strategies are dealt with separately in the academic literature: customisation by lock manufacturers in the West Midlands (Bryson *et al.*, 2008), skills and expertise development by the photonics industry in Rochester, New York (Christopherson, 2009), strategies related to the provision of services by Rolls Royce Aerospace (Neely, 2008), continuous product, production and marketing innovation by GlaxoSmithKline (Livesey, 2006), and manufacturing experiences to strengthen brand recognition by Mondelez International with Cadbury's chocolate factory tours in Birmingham, West Midlands (Mitchell and Orwig, 2002). However, this study learnt it was difficult to isolate and focus on any one strategy, as all sources of firm-based competitiveness are part of a single process of firms trying to maintain a competitive position in the marketplace. The analysis revealed how each strategy influences an aspect and development of another strategy.

Table 5.6 outlines all the different sources of competitiveness identified from the interviews within each of these strategies. These strategies are not isolated and are

interwoven, as firms claim *"it's the whole mix of things that has* [made us] *successful"* (E-S-Knitter-6, 2013), meaning, *"it really is a blend of* [all the strategies]" (E-M-Bobbinet-1, 2013) working together that produces inimitable forms of competitiveness. UK TT firms blend and combine the sources of competitiveness outlined in Table 5.6 in different ways to develop their own distinct forms of inimitability. UK TT firm's competitiveness strategies can be explained by an integrated approach to understanding firm behaviour:

Table 5.6: Technical Textile Firm-Based Competitiveness of Interwoven Strategies

Source of Strategy	Contribution to Inimitable Competitiveness
Cost-Based Competitiveness	
Balanced Sourcing	This strategy maintains the size of the firm and their production costs, by providing firms with flexibility to meet larger customer orders and offer a wider product portfolio by sourcing labour-intensive, low value-added TT products from subcontractors located in low-cost locations, whilst firms focus on the production of high value-added TT products at their UK site.
Consolidation	This strategy enables firms to acquire or absorb new resources (equipment) and develops their capabilities (skill set and knowledge), which increases the efficiency and performance of the firm without creating additional productive capacity or costs.
Lean Manufacturing	This strategy enables firms to operate production at a high capacity in the UK and increase their manufacturing output with less production space and a smaller workforce. Automation enables a smaller workforce to focus on value-added and sophisticated processes.
Place-Based Competitiveness	
Logistics	This strategy provides firms with a distinctive locational competitive advantage to competitors. Firms provide their customers with services including speed of delivery on low or no minimum order thresholds, and manage client relationships, by engaging in regular and local firm-to-client interactions to source and stimulate knowledge spillovers.
Skill & Expertise	This strategy is inherent and specific to the firm, providing them with inimitable capabilities. Firm-specific skill sets enable firms to innovate and produce a TT solution required by a customer and develop their credibility as an expert in the TT industry. Different types of expertise enable firms to develop and implement the different sources of competitiveness.

Table 5.6: Continued

Source of Strategy	Contribution to Inimitable Competitiveness
Innovation-Based Competitiveness	
Product Innovation Routines	This strategy enables firms to develop product innovations with customers as partners, which meet the requirements of specific applications and can lead to the certification of intermediate components in safety-critical industries, providing firms with market security and long-term repeatable client relationships.
Process Innovation	This strategy has enabled firms to upgrade their manufacturing processes through the implementation of sophisticated equipment to produce higher value-added TT products. It has also improved the productivity of their production processes and enabled firms to develop flexible production routines for just-in-time production and logistical responsiveness of bespoke and customised orders.
Machine-Based Innovation	This strategy enables firms to develop idiosyncratic production processes and produce unique and innovative products with built-in inimitable characteristics, by modifications and additions to their own equipment and machinery.
Service-Based Competitiveness	
Co-innovation	This strategy enables each product to become inimitable to copying behaviour, as each TT product is bespoke and customised. It requires a local interaction between the client and the firm to design the product and incorporate customer requirements.
Flexible Production System	This strategy enables firms to be flexible and respond to the changing demands of their customer to personalise a product. It is also a form of supporting their client and maintaining long-term relationships.
After-care Services	This strategy enables firms to develop credibility with their clients through regular service maintenance and repair to ensure TT component is performing.
Product & Market Analysis	This strategy assists firms to improve their future product developments and develop their own knowledge on TT. Product gap analysis and market expectation also stimulates further product orders with existing clients.
Client Relationship Management	This strategy maintains established relationships of an existing client base and provides firms with inimitable forms of competitiveness as relationships are time and place specific.

Source: Interview Data (2012-2013)

Cost-based strategies of *balanced sourcing* has enabled UK TT firms to focus their UK activities on high value-added TT products and reduce the size of their UK sites by sourcing labour-intensive, high volume and low value-added products from low-cost locations, which has subsequently assisted them in their *lean manufacturing strategies*. *Lean manufacturing* supports UK TT firms in maintaining their manufacturing systems and profitability, which is invested into their production capabilities (new equipment and high performance fibres) for their **innovation-based strategies**, to develop and produce an increasingly advanced and high value-added TT product portfolio.

Significantly, **cost-based strategies** of *lean manufacturing* is first informed by **place-based strategies** of firm's employee's *skills and expertise,* to install new equipment for automation, and second by their **innovation-based strategies** of *process innovation* to develop efficiency improvements and flexible manufacturing strategies. This has induced UK TT firm's **place-based strategies** to compete on *logistical sources of competitiveness* with flexible and responsive manufacturing systems, which in turn has stipulated firm's **service-based strategies** of providing just-in-time production, *speed of delivery* and *low-minimum orders* to maintain *client-based relationships*. The implementation of these strategies then returns to informing firm's **innovation-based strategies,** by influencing the nature of *product innovation*, as it has enabled firms to focus on high value-added TT products and *co-innovation processes*.

UK TT firm's **innovation-based strategies** of *co-innovation processes* depend on their **place-based strategies** of *firm-client proximity,* as well as their *skill and expertise capabilities* to develop and produce novel TT solutions. This process re-affirms firm's **service-based strategies** of producing *customised and certified products* for each particular customer, which consequently supports their *client relationship management* strategies. To produce exclusive TT products, firms have developed sophisticated **innovation-based strategies** of *machine-based innovation, the internal modification of firm's equipment and machinery*, which builds intellectual property into the product. Likewise, UK TT firm's **service-based strategies** of *product and market analysis*, which is informed by **place-based strategies** of *close proximity* for *customer interaction* to increase the knowledge base of the firm, supports firm's long-term capabilities in pursuing **innovation-based strategies** that revolve around novel *product innovations* of high value-added TT products.

This example highlights how UK TT firms are weaving together their own distinct sources of competitive advantages and strategies into a distinctive 'tapestry'. This competitive 'tapestry', or purposive interwoven competitive weapons (Rugman and Verbeke, 2002), provides firms with inimitable forms of competitiveness and differentiation, which is difficult to copy by their competitors (Bryson and Taylor, 2010). This thesis provides a significant contribution to the literature of how to understand the complexity of firm-based competitiveness, by examining the interwoven aspects of all competitive strategies. In particular, this thesis has developed a novel approach to

studying firm-based competitiveness of manufacturing firms located in a high-cost location, by blending non-price-based strategies with cost control mechanisms, which has not been widely considered in the latest manufacturing research (Mulhall and Bryson, 2013).

5.7 Summary

This chapter has explored the interwoven sources of firm-based competitiveness, which enables TT firms to maintain their manufacturing systems in the UK (Research Objective 2). It has built upon the previous chapter, which identified the changing competitive dynamics of the UK TT industry in the past ten years, and examined the competitiveness strategies developed by UK TT firms, in response to this external pressure. The sources of firm-based competitiveness have been identified through four main strategies related to cost-, place-, innovation-, and service-based competitiveness. It has examined the interwoven aspects of these strategies to understand how they provide UK TT firms with inimitable forms of competitiveness (Section 5.6). This is the first study in the manufacturing competitiveness literature, which has examined in detail all the different approaches together, rather than focusing on one competitive strategy in isolation.

The UK is a high-cost location for manufacturing processes due to higher localised input costs (Table 5.1). The location of UK TT firms is path-dependent and has been formative to their competitiveness (Martin and Sunley, 2010). A significant finding of

this chapter has been that firms have had to develop cost-based competitiveness strategies to enable them to afford to maintain their profit levels and manufacturing activities in the UK (Bryson and Ronayne, 2014). Despite the higher cost base, the geography of UK TT firms is critical to their inimitability and competitiveness (Bryson and Taylor, 2010; Hudson, 2010). Firms have had to employ a balance of cost control mechanisms with localised sources of competitiveness, which include expertise, logistics, customisation, co-innovation and services. These localised sources all require accessibility and nearness to market and have been incorporated into all of UK TT firm's competitiveness strategies (Bryson *et al.*, 2008). This has provided firms with a physical competitive advantage over their competitors, which are at a geographical disadvantage situated in low-cost locations (EEF, 2014; Foresight, 2013; Schroeder *et al.*, 2002).

This chapter has provided a further understanding on UK TT firms. It has identified that TT products are an example of hybrid products, which contain the combination of manufacturing inputs, for the product to be produced and function, with embedded services (Bryson et al., 2013). Firms have developed sophisticated strategies that enable them to focus on the continual innovation and production of high value-added TT products. These strategies are customer driven; they relate to working closely with customers and following their changing specific requirements to develop novel TT solutions. Machine-based innovation, the modification of existing equipment for intricate design to be built-in to products for inimitability, is a new source of firm-

based competitiveness that was identified in this chapter. Machine-based innovation enables firms to develop and produce innovative and exclusive TT products for clients. In return, some customers certify these TT components into the production of safety-critical end products, providing firms with market security and long-term repeatable client relationships. Client relationship management, regular firm-client interactions, and cross-fertilisation of applying knowledge developed from one market to an unrelated market for further innovation, prevents firms experiencing a negative lock-in of a decline in new customer orders or innovation stagnations with their established client base (Boschma and Frenken, 2006; Martin and Sunley, 2010).

Throughout this chapter, it has continually emerged how UK TT firms require flexible and responsive innovation and production routines to develop and implement the firm-based strategies discussed. This suggests that the adaptation of firm's innovation and production routines has therefore played a significant and instrumental role in the formation of UK TT firm's inimitable competitiveness (Boschma and Frenken, 2006). The next chapter identifies and examines the adaptation of these two particular routines (Aldrich and Ruef, 2006; Martin, 2010).

6 ROUTINES AND ADAPTATION: FOUNDATION OF FIRM-BASED COMPETITIVENESS

6.1 Introduction

External pressures in a firm's economic environment demands the adaptation and development of new routines (Martin, 2010). Routines are the organisation and management of firm-specific resources and capabilities into settled and repeated patterns of behaviour (Aldrich and Ruef, 2006; Nelson and Winter, 1982). Adaptation of routines involves a continual change or reallocation of how firms blend and organise their resources into distinctive capabilities (Chakravarthy, 1982; Frenken and Boschma, 2007). Adapted and adjusted routines support a firm's evolution trajectory to a new organisational form, which is more resilient to changes in their external environment (Martin and Sunley, 2010; Schamp, 2005). In the last ten years, the second adaptation period of the UK TT industry, there have been significant changes to firms competitive dynamics with an emergence of new competitors located in low-cost locations (Byrne, 2007). The previous chapter examined the interwoven competitiveness strategies UK TT firms have developed, in response to these new types of competitors. Firm's strategies are related to exploiting advantages linked to location and connectivity, which provides them with forms of inimitability, the differentiation of firms to

promote difficulty and prevention of competitors in attempting to imitate or copy their products and processes (Bryson and Taylor, 2010; Hoopes *et al.*, 2003). Routines are the foundation of firm-based competitiveness, as they govern firm-specific behaviour to deliver purposeful competitive strategies on daily basis (Boschma and Frenken, 2006). Two different types of routines have been identified from the empirical data, innovation and production, which have been adapted by firm-based processes and practices to support the development and execution of firm's competitiveness strategies.

This chapter examines the adaptation of UK TT firm's innovation and production routines (Research Objective 3). It is divided into six sections. The first two sections examine the adaptation of firm's innovation and production routines, which informs the implementation and delivery of their competitiveness strategies identified in the previous chapter. The succeeding two sections assess the adaptation processes of these routines. The third section discusses the adaptability of UK TT firms routines and investigates the local and external search processes, required by firms to generate new knowledge, which informs the modification and adaptation of their existing routines (Schamp, 2005). The fourth section examines the importance and development of UK TT firm's employees capabilities to successfully implement new and adapted routines (Boschma and Martin, 2010; Rigby and Essletzbichler, 1997). The fifth section builds upon Chapter 4 and advances the TT E-RBV framework, by developing a further

understanding on the adaptation processes involved to modify UK TT firm's innovation and production routines. The sixth and final section provides a chapter summary.

6.2 Innovation Routines: *"Centres of Excellence"*

Innovation routines are regular patterns of innovative behaviour that create and diffuse new products, organisational methods and production procedures (Dicken, 2011; EEF, 2013). Prior to the second adaptation period, UK TT firm's innovation routines were speculative. They would design products independent of customer demand and requirement. Firms would develop a constant stream of new products even if *"*[there wasn't] *an end market"* or any *"possibilities for that product going further"*, because *"*[they] *were just so keen to develop something"* (E-M-Weaver/Knitter/Nonwoven-1, 2013). UK TT firms have become increasingly conscious of their daily innovation routines, since their competitiveness is increasingly dependent on their innovation capabilities (Chapter 5).

Innovation underpins firm's competitiveness strategies, as it enables them to re-invent themselves through new and inimitable products and processes (Bryson and Taylor, 2010; Martin and Sunley, 2010). UK TT firms routines have become *"more reactive than proactive"* (N-M-[Narrow]Weaver-2, 2013), by focusing and incorporating the needs of their customers, rather than being led by technological developments (DRA, 2001). Firms are now "*very justified in what* [they do]*"* E-M-

Weaver/Knitter/Nonwoven-1, 2013) and *"only move to new technologies or new areas if* [they] *can see their customers growing alongside those sort of areas"* (N-M-Weaver-4, 2013). The development of co-innovation strategies, where firms develop and produce products in partnership with customers has resulted in 57.5 per cent (23/40) of the firms interviewed to radically adapt their innovation routines (Bryson and Rusten, 2011). Changes to their routines include the development of physical innovation spaces, procedures for product developments and R&D teams with strong employee engagement.

Significantly, the remaining 42.5 per cent (17/40) of UK TT firms have not implemented these changes or engaged in the adaptation of their innovation routines. This is predominantly due to a lack of surplus time capacity, financial resources and people:

> *"This is the problem with R&D in our industry, it's expensive to do and it would be brilliant if we could do samples, which we can do to a degree, but you're still limited because of the resources and the fact you've got* [to do the sampling] *on a production loom, which should be earning you money and it's not, because you're doing samples"* (E-M-[Narrow]Weaver-7, 2013).

This group of firms claim they use to have *"complete sample rooms at one point with people just doing nothing but design all the time, but those days have gone"* (E-S-[Narrow]Weaver/Knitter-2, 2013). This has been a negative consequence of the 2008 recession. Firms have made *"cut backs"* by first *"rationalising* [their] *time, so that* [they] *use it effectively",* and second by reducing the size of their workforce (section 5.2.2), making some roles redundant including new product development (NPD) roles (E-S-Nonwoven-5, 2013).

An additional reason to why this group of firms have not adapted their innovation routines is due to their customers. Firms claim they *"don't do enough* [innovation] *that would justify having anybody dedicated to doing it"* (E-S-Weaver-6, 2013), as *"some of* [their] *customers aren't perceptive to change, they've bought that for 120 years… and that's what they want"* (E-M-Bobbinet-1, 2013). Some of UK TT firm's customers do not want them to change or alter a specific product. This is especially the case for certified intermediate components, as an alteration would mean the end product, all of its components and following production processes would have to be reaccredited, which is time-consuming and expensive (Section 5.4.1):

> *"The reason we're an aerospace producer is because we can replicate today what we were doing 15 years ago and to a certain extent we're not trying to innovate with the traditional products because we would not be thanked for doing that, because of how our aerospace approvals work"* (E-M-Weaver-7, 2013).

This firm states how this smaller group of non-active product innovators (17/40 firms) are not adapting their innovation routines to implement the competitiveness strategies of co-innovation and product development processes. These firms are currently focusing on other strategies related to location (cost- and place-based competitiveness) or continuity of re-production capabilities for manufacturing and service repeatability of a specific product (Chapter 5). This is either because a firm's product portfolio is currently providing them with profit or their client base is not requiring these firms to change due to certification.

Innovation progression enables firms to enter new TT markets, adapt routines and maintain a sustainable, positive and evolution trajectory (Boschma and Frenken, 2006). Continuity of established innovation routines may cause these firms to become 'locked' on to this existing trajectory (Essletzbichler, 2009; Martin, 2010). As low-cost competitors catch up via their own product innovation routines and emerge on the market with similar products (Section 4.6), these firms could begin to experience a negative lock-in, meaning *"a slow and steady decline"* (E-M-[Narrow]Weaver-6, 2013). The remainder of this section examines the changes to the group of UK TT firms (23/40) that have adapted their innovation routines.

Innovation Spaces

UK TT firms aim *"to manufacture a product at the wish list of the customer"* (E-M-Nonwoven-3, 2013), by co-innovating with customers to develop novel TT solutions and becoming *"centres of excellence"* with their expertise capabilities by engaging in some speculative innovation (Chapter 5). To become more innovative and customer-focused, 57.5 per cent (23/40) of the firms interviewed have "*changed* [their] *working environment because it was felt* [they] *needed* [an] *innovation space"* (E-M-Weaver-Knitter/Nonwoven-1, 2013). Innovation spaces or TT design studios provide these firms with a customer service and product development space for their customers to visit and observe a firm's current product portfolio and capabilities (Section 5.3.2). These new and dedicated innovation spaces are similar to the function of a board meeting room, but are more open and informal working environments. They contain

previous product development examples for inspiration, and whiteboard space for production project planning and idea mapping (Factory Tour, E-M-Weaver-8, 2013).

A novel example of an innovation space recently developed by one of the firms is E-M-Weaver/Knitter/Nonwoven-1, which has developed a modern, brightly coloured and open plan space (Figure 6.1), for a more relaxed and creative innovation atmosphere (Company Website, 2015). It contains an open office workspace, a cinema space, business units, sofas and glass enclosed transparent meeting rooms, which all revolve around their *"product tree"* (Figure 6.1). The product tree is a visual reminder of their product development ideas. It [redacted] (Company Website, 2015), so *"every time* [they] *develop a new product* [they] *hang it from the tree, so* [they're] *continually seeing the products that are being developed"*.

Figure 6.1: Photographs of Innovation Space and Product Tree

[redacted]

Source: E-M-Weaver/Knitter/Nonwoven-1 Website, 2015

This innovation space replicates a fashion that comes from outside the firm, for example Google's California Headquarters (HQ) (Oksanen and Ståhle, 2013). It houses individual business units or termed as 'PODs' by the firm, which are all brightly and individually coloured sectioned areas (Company Website, 2015). Each POD has *"a business manager that is responsible for each of the PODs"*, it "*meets at least once a week"* and operates *"like a separate business within the company"* for each market area, for example composites or flooring. Each of the business units is provided with a physical coloured space (Figure 6.1) to nurture new ideas for each market they're responsible for. Each POD *"has a vision… it's all mapped out* [of] *where they're going, what their targets are and how they're looking"*. The PODs *"gain marketing insights"*, *"flesh out ideas"* and discuss new product developments and prototype results.

Every POD includes a cross functional team that consists of employees from purchasing, marketing, IT, testing, production, distribution and accounting (Company Website, 2015), which are *"all sitting together amongst each other… and communicating together*". This change in their innovation routine has enhanced interaction, communication and collaboration between employees in specific business development teams. This working practice of mind mapping and undertaking structured discussions on particular production projects, connects the different explicit knowledge pools of their employees for further knowledge creation (Bathelt *et al.*, 2004). Since the introduction of their innovation space, this firm has become much more conscious of their innovation routines, and as a result are more innovative as

"over the last three years, 29 per cent of [their] *products, were products* [they] *didn't make three years ago"*. Consciousness of their innovative behaviour, especially the quantity and type of new product innovation, is reflected in the design of the firm's innovation space by the product tree (Figure 6.1).

Research and Testing Laboratories

In the last decade, 91 per cent (21/23) of the firms that have adapted their innovation routines, have introduced and invested in new R&D and quality control laboratories:

> *"We now have a lab here, we have non-manufacturing capability which we would never have had in the past… we can do some mechanical testing of parts ourselves to give customers a technical service"* (N-M-Weaver-1, 2012).

UK TT firm's customers tend to dictate the technical specification of their intermediate TT product (E-M-Weaver-7). These firms now have *"*[their] *own in house testing facilities"* (E-M-Weaver-8, 2013) to test the physical parameters and performance of their TT fabric. This includes quality assurance (E-M-[Narrow]Weaver-4), colourfastness, strength, weight, PH levels, elasticity, compression, fibre structure and microbial testing (E-S-Knitter-5), flammability testing (E-M-Weaver-8), oil and water absorption and abrasion testing (E-S-Nonwoven-5). Firm's in-house laboratories are accredited, meaning firms *"send a report* [to their customers] *with all the deliveries and certificates of conformity showing how* [the TT product has] *performed* [in each of the required tests before dispatched to the customer]*"* (E-S-Knitter-5, 2013).

UK TT firms have to have their products, especially safety-critical and certified products, independently and formally tested and *"use extensively third party laboratories"* (E-M-Weaver-8, 2013). In-house testing is a new and additional service that firms provide to their customers (E-M-Nonwoven-7). It provides firms with substantial benefits, by contributing towards their competitiveness strategies, with control over quality, flexibility and speed of responsiveness for co-innovated product developments (Chapter 5):

> *"*[By having our own laboratories] *…we're able to do testing very quickly, new ideas, new developments, very short runs through our in house testing rather than waiting several weeks from a supplier* [external testing laboratory] *to get the information"* (E-M-[Narrow]Weaver-3, 2013).

Before sending a sample or final product to be tested and certified externally, firms undertake initial testing in-house for prototype developments. This adapted innovation procedure is time and cost effective. Testing is expensive (E-M-[Narrow]Weaver-7). By testing in-house, firms can continue to develop a new TT until they are sure it is meeting the specified certification standard (E-M-[Narrow]Weaver-3). When an external body tests the new TT development, it will therefore conform and pass first time, reducing the probability requirement of repeated testing. This is more time efficient in the product development process, as it saves sending the product back and forth between both the customer and independent testing company. It also reduces the waiting time in receiving multiple cycles of test results from test houses, which improves the lead-time in their speed of responsiveness and delivery.

As part of developing R&D laboratories, this group of firms have *"introduced new technical* [and] *product development teams"* (E-S-Knitter-5, 2013):

> *"We have to get involved with universities although we don't do it as well as we should and get the brains within our organisation so we've spent ten years building our own development resource department here… we kind of took the decision ten years ago* [that] *we need to be really in control of where we* [are]*, if we're saying our strategy is all about innovation, you've got to have the people to do that so we trained and trained and bought in expertise in order that we've got that resource and capability to do that"* (E-M-Weaver-2, 2012).

Firms are competing on the basis of their skill set to develop sophisticated TT innovations (Chapter 5), and *"*[are] *selling* [their] *knowledge and technical expertise"* (E-M-Nonwoven-3, 2013). To develop their R&D teams, firms have targeted and recruited *"people coming out of the universities"* (E-S-Knitter-5, 2013) with Master's and PhD degree level specialist textile expertise and skills. The R&D teams developed are an interdisciplinary mix with *"a whole range of backgrounds, chemist scientists, materials scientists"* (E-M-Nonwoven-3, 2013), mechanical engineers, product developers and textile technologists (Section 4.2).

UK TT firms technical teams are *"obviously heavily involved in* [the] *specification and testing of* [firms] *products"* (E-M-Weaver-8, 2013), and working on product developments and fabric analysis (Table 5.4). Significantly, R&D teams are increasingly involved in product development processes and visiting customers. One firm explains how their technical specialists are:

> *"Not sales guys by nature, but* [they] *would be able to sell a product a lot more effectively…* [they] *would be telling* [a customer] *things that they didn't even*

> *know… so to move forward to the next step we've got to use* [specialists] *who's knowledge of* [TT] *in the industry, again is brilliant, they are the guys that will move you on"* (E-M-[Narrow]Weaver-4, 2013).

This firm emphasises the change in TT working practices, with the development of their innovation-based strategies that focuses on co-innovation with customers (Bryson and Rusten, 2011; Bryson and Taylor, 2010). Firms compete on the basis of their expertise. As a result, their sales and customer recruitment routines have changed from *"customers coming to* [them]*"*, where firms did not try *"to tell customers what* [they did or] *…what capabilities* [they] *had and what* [they] *could produce,* [as they] *relied on customers knowing"* (N-M-Weaver-4, 2013). TT products have become increasingly technical and sophisticated, and this requires the involvement of firm's technicians speaking to their customer's technical people (N-M-Weaveer-1), in production projects and product development meetings (Chapter 5).

Employee Engagement

A significant adaptation of UK TT firms innovation routines is the engagement of their employees to be actively conscious of their daily innovative behaviour (Boschma and Lambooy, 1999; Rigby and Essletzbichler, 1997). Firms are undertaking "*a lot of work at the moment on employee engagement… so rather than one or two or three problem solvers,* [they're] *trying to get seventy or eighty problem solvers"* (E-M-Weaver-8, 2013). They are *"encouraging people to be more open minded" and "come up with new ideas"* (E-M-[Narrow]Weaver-5, 2013) *"for process changes, process developments,*

process improvements, product improvements [and modifications]*"* (E-M-Weaver-11, 2013).

Cross-functional teams or 'PODs' have been assembled *"that consist of people from the factory floor right through to directors"* (E-M-Weaver/Knitter/Nonwoven-1, 2013), for networking, idea mapping and structured discussions on particular product development projects and problem-solving workshops (Hansen and Birkinshaw, 2007):

> *"We involve everyone at different levels and different roles in various workshop activities where we have problems or where we want to make improvements, so we have a multi-functional team with engineer level people or technicians and shop floor operators, we listen to what they say in these workshops and ask them for how do we solve this, because we don't have an exclusive right to have the best ideas, we listen to what they think can solve it, and try really to engage them in the processes itself"* (N-L-Weaver-5, 2013).

These project teams encourage learning-by-interacting from employee collaboration and knowledge sharing across different departments of the same company, to initiate innovative ideas and behaviour (Gertler, 2003; Hansen and Birkinshaw, 2007; Maskell and Lorenzen, 2004).

Operating an open and flat organisational structure with strong employee involvement in problem-solving is "*how* [firms] *can improve* [their] *business"* (E-M-Weaver-11, 2013) (Schroeder *et al.*, 2002; Taylor, 2006). Employee engagement is increasing firms process innovation behaviour, which has contributed towards firms cost-based competitiveness strategies of optimising their production process to be more efficient

(Section 5.2.2) and inimitable with novel equipment modifications (Section 5.4.2). Employees are therefore actively aware and engaged in the daily production and innovation routines of the firm (Aldrich and Ruef, 2006; Bryson and Ronayne, 2014). Active awareness, engagement and regular innovative behaviour by employees moves the firm towards a positive and evolving path trajectory to adapt routines and prevent negative lock-in on an existing path (Martin and Sunley, 2006).

This section has examined the adaptation of 57.5 per cent (23/40) of UK TT firm's innovation routines. Adaptation has involved this group of firms transforming their working spaces, introducing in-house laboratories for testing prototype developments and for the shop floor to be actively engaged in new product developments through production project teams. They have introduced R&D teams with new knowledge and technical expertise by the recruitment of employees with specialist skill sets. This section emphasises the importance of employees in the adaptation of firm's routines to implement their competitiveness strategies, especially those that revolve around their innovation capabilities. UK TT firm's employees play a significant role in co-innovation procedures by their ability to communicate and demonstrate their expertise in product development meetings, as well as manage complex interactions and develop long-term relationships with customers (Chapter 5). The adaptation of innovation routines is interdependent to firm's production routines, it requires the adaptation of production routines to centralise these customer focused innovation projects. The next section examines the adaptation of UK TT firm's production routines.

6.3 Production Routines: Advanced and Just-in-Time Practices

Production routines are the day-to-day operational working practices of firms to produce outputs (Nelson and Winter, 1982). UK TT firms *"try to organise* [their] *factories with a prescriptive process so* [there is] *a recipe for* [each] *product, so you throw these raw materials in, you do this, and you end up with the end product"* (E-M-Weaver-2, 2012). Production of a TT requires the process division of routines in preparing the yarn, setting up the machine, the running of the machine, inspection and finishing of the product (Table 5.4). The different types of expertise within UK TT firms are *"specific to the processes that* [each employee is working] *in"* (E-M-Weaver-10, 2013). UK TT firms routines therefore revolve around the division of skills and expertise between workers (Simmie, 2010).

Innovation changes production routines by 'the implementation of a design for a new product, or of a new way to produce a product' (Nelson and Winter, 1982: 128). With growing competition in standardised TT products (Byrne, 2007), UK firms are *"pushing* [themselves] *up the technology scale"* (E-S-Knitter-5, 2013) and co-innovating with customers for a continuous 'renewal' of products (Chapter 5). Consequently, UK TT firms have *"become focused on service and the ability to make what people want"* (E-S-Weaver-6, 2013). Firms produce *"products* [that] *are technically very advanced"* (E-M-Nonwoven-7, 2013) in regulated markets of automotive and aerospace, military and defence, medical and healthcare (Chapter 4). Their key customers are influencing and driving firms competitiveness strategies of personalisation, flexibility and

responsiveness, which require the adaptation of production routines (Boschma and Frenken, 2006). There have been two key changes to UK TT firm's production routines. First, the introduction of advanced and structured processes by 57.5 per cent (23/40) of firms for the production of accredited products, which provides these firms with inimitable competitiveness, in particular with long-term protection from competitors and market security (Section 5.4.1). Second, the development of flexible working practices and planning schedules, which has been undertaken by all of the UK TT firms interviewed, in the adaptation of their production routines.

Advanced and Structured Production Routines

Certified products for safety-critical markets such as aerospace, military and defence, and personal protective equipment (PPE) have a long life cycle for up to 40 years (Chapter 5). Customers in these markets are concerned *"about reliability, …quality and consistency*" (E-S-Knitter-5, 2013). To become an approved and qualified supplier in these markets, lead customers of firms supply chains, for example Airbus or Rolls Royce, independently audit TT firm's production routines *"with a fine tooth comb"* (E-M-[Narrow]Weaver-3, 2013):

> *"We have just relatively recently gone through a primary structures aerospace qualification program, so we've really had to step up our standards in terms of management of change, procedures, foreign object defects or FOD as it's called, which is the norm as far as aerospace industries are concerned, yeah that's been probably the biggest shift* [in working practices]*"* (E-M-Nonwoven-3, 2013).

Lead customers of safety-critical industries (Chapter 4) run their manufacturing systems *"very strictly, so basically they turn round and say* [to their suppliers] *you need to now have this and you've got to do this"* (E-M-[Narrow]Weaver-4, 2013). UK TT firms have been forced by lead customers to adapt their production routines, which meets the expectation of these customers to match their supply chain and operate advanced and *"world class manufacturing businesses"* (E-L-Knitter-8, 2013).

Firms have had to adapt their production processes to *"look and act like a modern manufacturing outfit"* (E-M-[Narrow]Weaver-1, 2013) and develop *"prescriptive concrete steps to verify quality"* (E-S-Knitter-6, 2013):

> *"We've got rid of a lot of the black art that sort of used to exist because by virtue of having to make an aviation article where you must have consistency of product at all times and you have a certification process, which means everything is traceable, the people are traceable who made it and the materials are traceable all the way through and the process is, and the machines are traceable, so we have quite controlled processes"* (E-M-[Narrow]Weaver-6, 2013).

In the twentieth century, *"black art"* in production was known as the *"little tricks and tweaks"* that specific employees did during production and *"kept a secret"* in their own *"little black notebooks"* (N-L-Weaver-5). However, *"of course when* [these employees] *left and* [firms] *put a new guy on* [the same machine] …[they] *got quality issues and wondered what the hell was going on"* (E-M-[Narrow]Weaver-3, 2013). Over the past five years, firms have begun to collect this "*secret*"' information from older employees especially, and *"now everything is very well documented to how machines should be run, temperatures, settings, speed etc."* (E-M-[Narrow]Weaver-6, 2013). This highlights

how firm's core competencies are tied to their employees (Storper and Walker, 1983). Employees have intangible capabilities of embodied tacit knowledge that is difficult to exchange and transfer from one employee to another (Boschma *et al.*, 2009; Hoopes *et al.*, 2003). Further research is needed on firm's documentation process of their employee's micro-routines, practiced processes and tacit knowledge.

UK TT firms have followed their customer's expectations and requirements and adapted their production routines to incorporate procedures of quality and traceability. Firms have thorough inspection processes on every individual product and include traceability records on *"who's made it, on what machine* [and] *on what day",* as *"it's important for the company in question for their process and their quality control and feasibility* [that the product] *can be traced back to this machine and this knitter*" (N-S-Knitter-2, 2013). In safety-critical products, this is especially important for investigation and evidence reporting when an incident occurs: *"we have had examples where Airbus have turned up and said look we had a tail end fall off a plane last year, you're the supplier of the fabric please can you produce your inspection* [and approval] *records"* (E-M-Weaver-7, 2013). This production routine is associated to firm's cost management strategies of efficient, responsive and quality aware processes (Section 5.2). It increases accuracy in the production of the product to reduce waste and ensure the manufacturing process meets the accreditation approvals of the client (Inman *et al.*, 2011).

The ability of UK TT firms to *"replicate today what* [they] *were doing 15 years ago"* (E-M-Weaver-7, 2013) is essential for certified TT products, since customers are not likely to substitute firms once approved due to the high cost of re-certification (Chapter 5). As an approved supplier for certified TT products, firms are awarded long-term contracts and have to *"guarantee that* [they] *can continue producing* [the specific product] *on a current machine"* (E-M-[Narrow]Weaver-3, 2013). This means firms are *"running some old shuttle looms and old equipment which is very profitable for* [them]*… and* [they are] *having to try and work out different routes* [methods of repair and maintenance] *to keep them going"* (N-M-Weaver-4, 2013). UK TT firms have developed maintenance schedules to continuously service their machinery. A handful of firms even stop production one day a week to dedicate this time to maintenance. Through *"preventative maintenance"* (E-S-Weaver-6, 2013), some equipment and machinery *"will last thirty, forty,* [or even] *fifty years"* (E-M-[Narrow]Weaver-5, 2013).

The changes in UK TT firms production routines to become advanced and structured reveals how not all the products firms produce are the same, and different products require different routines, which each have a *"pre-described route"* (E-M-Knitter-4, 2013). Some production routines may apply to all products where there is a 'well-specified technical routine' (Nelson and Winter, 1982: 14) of how to produce a product, especially when *"the basic process of weaving hasn't changed in hundreds of years"* (E-M-Weaver-8, 2013). However, in other cases, routines may be product specific (Frenken and Boschma, 2007). This involves *"pre-form methods"* (E-M-Knitter-4, 2013),

in choosing which machine to produce a certain product on, as *"one* [machine] *is geared towards manufacturing one type of product and one is geared towards manufacturing another"* (E-M-Nonwoven-3, 2013).

Technology, therefore, limits UK TT firm's routines or specifies them. For example, weaving is a slower and more labour intensive process compared to knitting, which is automated (Thompson, 2002). It is a manual process and a lot of production time is spent winding the yarn onto a creel or a beam and setting these up onto the machinery, known as a loom (Burton, 2013):

> *"It's usual when the loom stops, that loom might be stopped for a couple of weeks maybe just to change the canisters, a loom probably out of 52 weeks of the year only runs for 40 weeks"* (E-M-Weaver-2, 2012).

Depending on the type of loom a firm possessed, preparation of the production process can take between two hours for firms weaving from a beam, where yarns can be prepared away from the loom, to ten hours for firms weaving from a creel which is permanently attached to the loom:

> *"We don't have the benefit that some people who weave from beam have where they can do almost all the set up offline and then within a couple of hours drop in a beam shaft, and weave, from our perspective we are still doing the creeling offline and then it could be like 10 hours before we're weaving, I'm envious of some of the people who only takes 2 hours to change over"* (N-W-Weaver-1, 2012).

UK TT firm's path dependency, the decisions of previous owners and employers, influences their location, production process type and ultimately the type of TT product they produce (Chapter 4). Established Firms have retained existing routines

that have been 'proved – or been perceived as - beneficial' (Aldrich and Ruef, 2006: 23), as with standardised weaving production routines discussed above (Burton, 2013). Newly Created Firms, which are spinoff companies, have replicated routines and competences from their parent companies (Martin and Sunley, 2010; Stam, 2010). Routines are inheritable from parent companies, as well as copying behaviour of firms, as a result of agglomeration economies mechanisms (Boschma and Wenting, 2007). Unless production routines are challenged for adaptation, path-dependent behaviours will continue along well-established trajectories (Simmie, 2010).

Just-in-Time (JIT) Working Practices

The main adaptation mechanism UK TT firms have adopted into their routines is Just-in-Time (JIT) manufacturing approaches (Foresight, 2013; Inman *et al.*, 2011), which has informed their customer-led competitiveness strategies of lean, efficient and responsive production processes (Chapter 5). The adaptation to JIT production routines has been critical, as customers *"don't want to commit to stock or they don't want to commit to forecasts"* (E-S-Knitter-6, 2013), so orders *"will change on a day by day basis, hour by hour sometimes"* (N-L-Weaver-5, 2013). Firms have developed comprehensive planning schedules to *"be able to accommodate"* flexible orders (E-S-Knitter-7, 2013) and for *"better visibility of lead times, so when the customer phones up* [they] *can quote an accurate lead time for* [them] *to manufacture and dispatch the goods"* (N-M-Weaver-4, 2013). Planning is done on a daily basis and firms use historical perspectives (E-M-Weaver-7) *"to forecast three months* [ahead] *of what they*

think is going to happen with each client" (E-M-Weaver-12, 2013). Accuracy of their order predications increases nearer to production: *"the twelfth week is something like 30 per cent accurate, the sixth week is about 50 per cent accurate and the* [following] *two weeks is what it is"* (E-L-Knitter-8, 2013). With long-term customers and when firms are contracted as the specified TT supplier, they have *"programme visibility"* (E-M-[Narrow]Weaver-1), which gives *"a sort of reliability index and a confidence"* (E-M-Weaver-12, 2013). For example, lead customers like Rolls Royce or *"Airbus, know how many planes they're going to make in June 2018 so* [firms] *have annual contracts and there's very little deviation between the production and expectations each month*" (E-M-Weaver-7, 2013).

To operate JIT production routines, UK TT firms have introduced and employed transparency procedures. First, 70 per cent (28/40) of firms have *"re-organised the whole of their production"* units (E-S-Knitter-5, 2013) and *"even went to the trouble of moving looms around the factory to make the process flow better"* (E-M-[Narrow]Weaver-3, 2013). Second, all the firms interviewed are providing their employees with as much information as they can (E-M-Bobbinet-1). Management conduct regular meetings with their employees on the shop floor at the beginning of each shift to discuss *"what's happening today: …who's doing what, who's doing where, and where are we?"* (N-S-Knitter-2, 2013).

To conduct fluid production routines on a daily basis, firms are *"trying to make the process a lot more visual, so if* [they] *can see it* [they've] *got a chance of controlling it"* (E-M-Weaver-8, 2013). Information *"which* [they've] *never publicised or displayed before"* (E-M-[Narrow]Weaver-1, 2013) is now visually displayed and openly communicated on large whiteboards to *"keep everything live and in the air"* (N-S-Knitter-2, 2013), and employees can visually adjust production planning and record any issues accordingly. In doing this, firms have assessed the risk in knowledge or intellectual property leakage from employees, via mobile phones, informal social networks between competitor firms and labour mobility between TT firms (Granovetter, 1973; Power and Lundmark, 2004; Zander and Kogut, 1995). Firms are first *"selective with who* [they employ and] *work with"* (E-M-Nonwoven-7, 2013). Employees are then *"signed up on non-disclosure agreements"* and *"non-competitive agreements"* to protect firm-specific knowledge, as part of their contract of employment (E-S-Weaver/Knitter-1, 2013). Once employed, firms *"seem to be very good at retaining staff"* (N-M-Weaver-4, 2013) with *"very good long service and a very stable set up"* (E-S-Nonwoven-5, 2013). In addition, firms claim due to production process divisions with routines revolving around the division of skill sets between workers (Simmie, 2010), shop floor workers:

> *"Aren't generally in an area where they'll get any knowledge that would be damaging, they'll probably learn, it's a bit like making a cake, they'll learn how to grease the tin and they'll learn how to turn the over on but that doesn't teach you anything. You know you can do three out of the eight bits but you've got know all of the eight bits, how to test it, and how to check it"* (E-M-[Narrow]Weaver-1, 2013).

This highlights how firms have adapted their production routines to incorporate the protection of intellectual property in advanced processes by developing a controlled environment of how employees engage and operate in the process.

The raw materials of UK TT firms are technical fibres and yarns supplied by chemical TNCs (Braddock-Clarke, 2007a), and when purchased from the Far East it can take at least six weeks to be delivered (E-M-[Narrow]Weaver-4). For quick responsiveness to customer orders, firms *"predict how much yarn* [they] *use of each particular yarn type so that for some of those yarns* [they're] *holding stock,* [they] *can then cut that lead time by the fact that* [they're] *not waiting* [for the yarn to be delivered]" (N-M-Weaver-4, 2013). Similarly to respond, customise and deliver a TT product at great speed over their competitors (Bryson *et al.*, 2008), some firms have *"always got a certain amount of what* [they] *class as standard products on the shelf ready to go… which is loom state, un-dyed product* [with no finishing or chemical treatment]*"* (E-M-[Narrow]Weaver-4, 2013).

Automated systems and equipment in UK TT firms production processes are enabling instantaneous flexibility to customer orders in production routines:

> *"That's the latest generation of knitting machines, fully computer controlled, patterns go onto a USB stick and are downloaded onto the machine, you can then edit the programme on here, it's all touch screen, you can knit a piece and if it's a bit big or a bit small, you can alter the sizes on here"* (N-S-Knitter-2, 2013).

Automation of lower skilled and labour intensive production tasks has enabled firms to reduce the size of their workforce (Florida, 1996; Hudson, 2010), hence now they *"can have an operative running two or three machines, whereas before it was one operative per machine"* (E-M-[Narrow]Weaver-3, 2013). Previously, on the shop floor if an employee *"ran machine 31, he ran machine 31"* (E-M-Bobbinet-1, 2013). Equipment was not regarded as *"loom number 23, it was Billy's loom because Billy had worked on that loom for thirty years"* (E-M-[Narrow]Weaver-3, 2013). For flexible production routines, firms have deliberately developed the skillset of their workforce (Section 6.5) to be *"multi-skilled, so that they're trained across different disciplines"* (E-S-Weaver-6, 2013). By ensuring that employees *"can do all the jobs* [in production]*"* firms are less dependent on key individuals. As one firm explained, if *"Fred's off and the process can't start, somebody* [can] *fill in and somebody* [can] *back the other guy somewhere else, it's a constant process of moving people around to fill the gaps where they need to"* (N-L-Weaver-5, 2013). As a result, UK TT firms can run constant production 24 hours a day, five days a week (24/5) and *"have a lot less factory shutdowns than* [they] *used to,* [and they can even] *try and work through some of the holidays"* (E-S-Weaver-6, 2013).

With changes in production routines and because firms have reduced the size of their workforce with lean manufacturing strategies and automation (Section 5.2.2), employees *"have to be much more flexible,* [and] *they're much more involved"* (E-M-[Narrow]Weaver-6, 2013). UK TT firms workforces have been empowered to take

ownership of these new production routines and they now decide *"what goes on those* [information and production planning] *boards, they decide what they track down to the senior people in production to ensure that it's aligned with the company's requirements"* (N-M-Weaver-1, 2012). Employees on the shop floor are more responsible for production and confident to make decisions without management (E-M-Weaver/Nonwoven-1), as *"they're not reliant on somebody telling* [them] *what needs to be done next"* (E-M-Weaver-2, 2012). The organisation of a firm reflects its learning capabilities (Lundvall and Johnson, 1994: 39). UK TT firms are operating flat structures with strong employee involvement, which is creating collective learning and providing a mechanism for the transfer of tacit knowledge (Kogut and Zander, 2003; Taylor, 2006). In adapting routines, firms are therefore relying on the teamwork of their employees to rotate roles, have ideas and become problem solvers for flexible, efficient and continuous production.

Previously, UK TT firms mature manufacturing processes involved a command and control organisational structure (E-M-Weaver-8), *"black art"* production secrets held by specific employees (E-M-[Narrow]Weaver-3), and immobility of labour on the shop floor with individual ownership over machinery (E-M-Bobbinet-1). Firms have transformed these production routines to new and advanced organisational forms to implement the following competitiveness strategies (Foresight, 2013): cost management for lean and efficient processes, customer service strategies of flexibility, co-production and customisation, and logistical strategies of responsiveness, delivery

speed and low-minimum order thresholds (Chapter 5). Adapted production routines revolve around the certification of intermediate TT products, with high quality and advanced procedures for traceability and consistency (Bryson and Ronayne, 2014). The development of a complex and multi-skilled labour force has been critical for firms to employ flexible, fast and efficient production processes (Christopherson and Clark, 2007; Kalafsky, 2008).

This section and the previous section have examined the adaptation of UK TT firm's innovation and production routines and discussed how the different changes are the foundation to informing the implementation of their competitiveness strategies (Chapter 5). Having considered how the adaptation of these routines relates to the competitiveness of UK TT firms, the next section builds upon this by examining how firms have achieved the adaptation of their routines. It will discuss the adaptation processes of retention, search and selection, which determine the adaptability of firm-based routines (Boschma and Frenken, 2006; Schamp, 2005).

6.4 The Adaptability of Routines: Retention, Search and Selection

Adaptation of routines needs to be *"constant"* (E-S-Nonwoven-5, 2013) and *"an ever-evolving process"* to *"continuous improvement"* (N-S-Knitter-2, 2013). As 'organisations compete on the basis of their routines' (Boschma and Frenken, 2006: 278), adaptability, a continual process of change in firms routines, is critical to thrive and

perform (Martin, 2010; Schamp, 2005). UK TT firm's external economic environment has introduced new pressures, competitors and technological developments (Section 4.6). The adaptability of routines determines the firm's capacity to change, which sustains their competitive position and their ability to evolve along a positive trajectory (Boschma and Frenken, 2006; Hoopes *et al.*, 2003).

Established routines can be retained due to certification of products and long-term client relationships, whereas adaptability may be constrained or restricted by firms path-dependent processes, as well as their current decision-makers (Martin and Sunley, 2006; Nelson and Winter, 1982):

> *"The main challenges at the moment are sort of modernising the way we do things because the company has only ever had two, well I'm the third managing director since 1950, so we had one guy for twenty-four years and another one for twenty-six years… and it's been a sleeping company for twenty odd years"* (N-M-Weaver-4, 2013).

Routines are durable and 'often retained and defended by actors with vested interests long after changes in the external conditions have made them redundant' (Malmberg and Maskell, 2010: 393).

Since 2000, *"there has been a reasonable evolution of senior management"* in 52.5 per cent (21/40) of UK TT firms *"from effectively the management that was running the business in the 1980s and 1990s"* (E-M-[Narrow]Weaver-1, 2013). Firms have changed the composition of their management team by introducing new directors *"to bring in a*

fresh pair of eyes and say well actually the real world has moved on, we now need to move forward to keep up and stay ahead" (E-L-Knitter-8, 2013). These new decision-makers intend *"to transform the business,* [by] *bringing in* [new] *policies and procedures, best practices, and making* [these firms] *truly world class organisations that can manufacture out of the UK"* (E-L-Knitter-8, 2013). The introduction of new directors and change in management team has driven the adaptation of these firm's routines (E-S-Knitter-6), as *"there's been an underlying principle whenever anybody is brought into the business they're better than the person they're potentially going to be replacing, that* [decision] *is conscious"* (E-M-[Narrow]Weaver-1, 2013).

Previously, UK TT firms have been sub-conscious of some repetitive routines, where firms *"knew how to do it because* [for the past twenty-five years they've] *always done it this kind of way"* (E-M-Weaver-2, 2012). In the second adaptation period, firms became increasingly aware and conscious of their existing routines, which enabled them to challenge and adapt their innovation and production routines in response to changing competitive dynamics (Martin, 2010; Martin and Sunley, 2006). Firms searched and selected new organisational routines, in the knowledge that others in the TT industry were doing the same (Essletzbichler and Rigby, 2007).

Search involves the evaluation of current routines and the decision to engage in adaptation processes of modifying, changing or even replacing routines (Nelson and Winter, 1982; Simmie, 2010). Firms develop their knowledge base and organisational

practices in response to constantly changing market and regulatory conditions, which informs the adaptation of their routines (Hodgson, 2009; Martin, 2010; Simmie, 2010). The organisational learning of firms, how they acquire, generate and interpret new information (Aldrich and Ruef, 2006), provides them with agility and supports the adaptation of their own routines (Boschma and Frenken, 2006; Penrose, 1959). Firms learn internally from their own employees and experiences, and externally from other firms and organisations they have linkages and interactions with (Cooke and Laurentis, 2010).

Local Search Process

Internal organisational learning is to Nelson and Winter (1982) a 'local search process'. Firms exploit their internal knowledge pool, which they have built up over time (Boschma and Martin, 2010). Employees of UK TT firms each have their own embodied tacit knowledge and experiences, developed from their employment in the daily routines of their firm (Dicken, 2011):

> *"*[The workforce are] *consulted a lot more, they get involved, if we're looking to a new process or want to improve the workplace we involve them in that, we get their inputs because they're doing the job everyday whereas I'm looking at it, they're doing it"* (E-S-Knitter-6, 2013).

Firms are increasingly consulting with their employees as significant sources of knowledge (Kogut and Zander, 1992), as they have a pretty good sense of which solutions are viable in problem-solving situations (Hansen and Birkinshaw, 2007).

Experimental learning amongst their employees enables existing routines to be modified or transformed (Essletzbichler and Rigby, 2007). Employees absorb new knowledge and learn by fast trial and error processes to assess quickly which modifications can be successfully implemented into their routines (Boschma and Frenken, 2006; Nelson and Winter, 1982):

> *"Another thing we believe in is the feel faster approach, get a product out there quickly, get it tested, it's either going to work or it won't and move onto the next thing, don't dwell on it and then fail way down the line than fail fast, so last month for example our rapid prototyping team put out 46 different prototypes to different companies in different market areas for trialling so kind of emphasises the focus we've got on getting new things out there quickly to market, seeing what* [customers] *are thinking, taking on what's worked from there and developing them further"* (E-M-Weaver/Knitter/Nonwoven-1, 2013).

To select ideas, the 57.5 per cent (23/40) of firms that have adapted their innovation routines (Section 6.2), have become *"more focused on things now and if projects aren't working* [they] *chop them off rather than carrying them on"* (E-S-Nonwoven-5, 2013). These firms have developed efficient learning processes in adapting their innovation routines successfully. When experimenting with new sources of inputs, new processes of production and new product enquiries (Essletzbichler and Rigby, 2007), firms review if ideas fit within their capabilities and organisational form, as well as assessing if they make economic sense to continue to pursue

Labour mobility is one of the key mechanisms through which knowledge diffuses (Boschma *et al.*, 2009: 169). Movement of labour between firms is assumed to contribute further knowledge creation, as well as change the internal knowledge pools

of firms (Power and Lundmark, 2004). Boschma *et al.* (2009: 173) state 'little attention has been drawn to the type of knowledge and skills that are transferred between firms through job-hopping'. They found in their study that new employees with related skills, but not similar to the existing knowledge base of the firm, is the most relevant to a positive performance in firms (Boschma *et al.*, 2009).

UK TT firms have always employed new but textile related labour from their industrial networks (Boschma and Martin, 2010; Roper *et al.*, 2008). This could be from a customer, supplier or a competitor to exchange knowledge and learn from these firms (Boschma *et al.*, 2009). Most of the TT firms *"have a policy of employing people who work for the competitor, in order to bring information in"* (E-M-Weaver-2, 2012). Firms have employed mobile labour with diversified but related skill sets to provide them with further knowledge and assistance in adapting their production routines (Table 6.1).

Table 6.1: Examples of Labour Mobility Recruitment Influencing Routine Adaptation

Firm Example	Mobile Labour Type	Routine Adapted
E-M-Weaver/Nonwoven-2 (The New Employee) *"Well I actually worked for a supplier, a machinery and plant equipment supplier before I came to work here…* [In 2007]*, when we got the tufted* [machine]*, we had major development work to do, we had a machine and we had sources of raw material but we had to come up with the product range and we did that…* [and] *that was the point where I became involved because of my background and gave them the ability to do that, so I came on board initially to get the synthetic grass product up and running and into the market"*	Employee from machinery and equipment supplier	**Production Routines:** New product routine New equipment New production line in factory

Table 6.1: Continued

Firm Example	Mobile Labour Type	Routine Adapted
E-M-[Narrow]Weaver-5, Interviewee 1 (The Employer) *"We bought a new quality manager who worked for another weaving company, he started in April* [Interview was in July]*, and so he's very good, he's got great product knowledge…* [The company he came from]*, we don't compete, we weave slightly different things… he comes from a company that wove products that went into aerospace so in terms of quality systems and requirements he knows his stuff"* **E-M-[Narrow]Weaver-5, Interviewee 2 (The New Employee)** *"I always think you've got the extreme example of 100 per cent effectiveness at one end of the spectrum, and 100 per cent efficiency at the other end of the scale, somewhere on that line is where we are and I think we could be a little bit further along that line, I mean for instance we don't have any proper Enterprise Resource Planning* [ERP] *systems, and we don't have proper* [records] *of materials, so all this stock has to be monitored in people's heads… and again like at E-M-[Narrow]Weaver-6* [where this employee worked]*, we had quite a well developed ERP system, that billed the materials, routines and costings etc. …I'm worried that we don't have a big enough handle on the actual elements of the cost, but* [all of] *this is what I'm trying to talk to the MD about"*	Employee from a non-competitor related TT firm	**Production Routines:** Efficiency improvements Recording & traceability systems

Source: Interview Data (2013)

In these two specific examples (Table 6.1), labour was employed from related firms in the TT industry for their background knowledge for a new product development (E-M-Weaver/Nonwoven-2), and their experience in operating and implementing efficient and traceable production routines (E-M-[Narrow]Weaver-5). New employees are

required with specialist knowledge to assist firms in their adapted innovative routines (Christopherson and Clark, 2007; Hansen *et al.*, 2013). One firm is developing new production routines in three-dimensional weaving of carbon-fibre for composite applications (Chapter 4), and are *"looking at composite testing, so* [they've] *got a good engineering graduate who will become a composite testing expert… he's got a good basis and knowledge foundation to do it"* (E-M-[Narrow]Weaver-1, 2013). This local search process of recruiting new and specialised labour, merges with firms external search processes, by the search for expertise and knowledge outside of the firm when they cannot find it within (Boschma *et al.*, 2009).

External Search Process

Openness to external economic environments enables firms to learn of newly emerging technologies, tap into divergent knowledge bases and develop new ideas and practices (Laursen and Salter, 2006; Maskell and Malmberg, 1999a). To inform the adaptation of their routines, UK TT firms have engaged in external search processes for better technologies (Rigby and Essletzbichler, 1997): *"It's just being out and about, it's just being in a market place, we have always kicked people out from here and to just go out… that's where you pick things up*" (E-M-Weaver/Nonwoven-1, 2013). The majority of UK TT firms external learning has therefore occurred through long-term relational contracts with suppliers and customers (Maskell and Malmberg, 1999a; Schroeder *et al.*, 2002), as firms claim to *"learn an awful lot by talking to customers"* (E-M-

[Narrow]Weaver3, 2013) and *"a lot of ideas and developments come from suppliers"* (E-M-Weaver-7, 2013).

Firms obtain information from their customers that are driving new product developments, and from their supplier's, which introduce new fibre and machinery developments (Asheim and Isaksen, 2002; Kakkad, 2009):

> *"You've got your yarn suppliers themselves, which you're often seeing developing a new type of yarn that does fancy things and you learn from that… I was introduced to a yarn that glows in the dark, so straight away I'm thinking well for anything that's height safety, especially in this country where it's going dark at 3pm* [in the winter months] *and you've got some guy up a telegraph pole, you've got your reflective yarns and they're fine when light hits them but the glow in the dark yarn is charged by UV so throughout the day it's charging, and you only need to put a few strips on to the webbing itself and then at night time it glows"* (E-M-[Narrow]Weaver-4, 2013).

An introduction to a new yarn by their supplier, led this firm to a new product innovation and consequently to the development of a new routine to incorporate this product into their current production systems (Boschma and Frenken, 2006). UK TT firms have invested in long-term and close relationships with suppliers and customers, as firms recognise that collaboration speeds up the pace of new product innovations and improves product quality and performance (Saxenian, 1991).

In the UK, universities and research institutions are where significant TT R&D activity is undertaken (Alliance, 2015). Universities should therefore appear to be a key access point for firms to learn about the latest research and technological developments in TT

(Benneworth and Hospers, 2007). In the UK, there are eleven universities that operate in the principal TT regions of the North West and East Midlands, which offer a wide variety of courses and expertise in related TT areas (Table 6.2). The main avenue for 15 per cent (6/40) of firms to work with universities are joint technology innovation programmes, which are initiated and funded by the government (Rusten and Bryson, 2010):

> *"Well there are obviously collaborative projects, you know the sort of Technology Strategy Board* (TSB) *type stuff which is by and large, they're research based projects so you do get information and benefit from those sort of activities"* (E-M-[Narrow]Weaver-1, 2013).

These joint innovation programmes enable firms to learn about current research and innovations in TT technologies. Collaboration between firms and universities can promote the development of new products by integrating diverse and complementary competencies (Maskell and Malmberg, 1999a). One programme enabled one firm to enter into a new market sector from a product innovation project, *"we probably had our early introduction to* [the medical market] *through the University of Bolton and we started developing 3D fabrics for the orthopaedic bandages"* (E-S-Knitter-5, 2013).

Table 6.2: Location of UK Universities with Technical Textile Research

Region	University*	Number of Universities	Number of Firms
Scotland	• Heriott-Watt University • University of Abertay • University of Strathclyde	3	5
North West	•University of Bolton •University of Manchester •University of Salford	3	13
East Midlands	•De Monfort University •Nottingham Trent University	2	10
South West	•Brunel University •Kingston University of London	2	3
Yorkshire & The Humber	•University of Leeds	1	5
West Midlands		0	2
Wales		0	1
Northern Ireland		0	1
	Total	11	40

Source: UKTI (2011a) and Interview Data (2012-2013)

**University and Region are presented in no particular order.*

In the past, firms have connected with UK TT university research departments and *"picked* [their] *brains a few times and used their sort of skills to give* [them] *a bit of advice"* (E-M-[Narrow]Weaver-5, 2013). However, it is noteworthy that 85 per cent (34/40) of the firms interviewed (a different group of firms to those involved in joint innovation programmes discussed above), are *"not positive about* [working with universities]*…* [and] *don't want to try and make out it's fantastic because actually a lot* [of their] *experiences hasn't been"* (E-S-Nonwoven-5, 2013. Most attempts for firms to collaborate with universities have been unsuccessful and disappointing:

> *"To give you an example we had a problem with one of our yarns… and we wanted to understand why the yarn was shrinking after it had been made into a product so it's a simple ring fenced here's the yarn, here's how it's knitted, investigate why it shrinks and give me a solution, it's not rocket science but it's a good research project so we went to Leeds University… they came to us with a £60,000 fee, well that never went anywhere, I did it for $5000 at IIT in Delhi so there's a bit of research that's been done at Delhi when it could have easily been done here, just disappointing you know"* (E-M-Knitter-3, 2013).

UK TT firms claim there is a gulf between the academic research occurring at universities and firms commercial interests (E-S-Nonwoven-4), especially with timescale and their fee structure:

> *"If you've got a project that you want to drive, you can't wait for funding, you can't wait for somebody to get their next PhD or their next research grant it's just working with treacle you can't do it, so if you want to get a product out there then don't touch universities"* (N-S-Knitter-1, 2012).

These examples provide significant and contradictory evidence to the innovation clustering literature on the strength of university-industry links, especially with firms in the same region (Asheim and Gertler, 2005).

To stay abreast of the latest technological developments in the UK TT industry and their customer's markets, firms are now trying to *"ensure that* [their] *people are constantly exposed to new ideas and not isolated or becoming out of date"* (E-M-[Narrow]Weaver-6, 2013). Significantly, 92.5 per cent (37/40) UK TT firms learn about new technologies and update their knowledge on the TT industry, by networking with employees of different firms and 'being there' at industry events and trade shows (Asheim and Isaksen, 2002; Gertler, 1995; Storper and Venables, 2004). Industry

events include cluster organisation group meetings, which can be related to TT like NWtexnet or markets, such as the North West Aerospace Alliance for firms producing TT composites. Networking at these events enables firms to discuss with other firms in their industry or market *"how to move forward"*, as well as provide serendipitous meetings with unrelated companies that have *"technologies* [they] *might be interested in"* for a joint product development venture (N-M-Weaver-1, 2012).

Trade shows provide firms with *"access to either different ideas that's stimulating or access to kit* [machinery] *that* [they] *don't have, or access to levels of expertise that* [they] *don't have and sometimes it's just* [gaining] *a different perspective"* (N-L-Weaver-5, 2013). Techtextil is the *"premier technical textile exhibition in the world by far"* (E-M-Nonwoven-7, 2013). Techtextil is visited by 50 per cent (20/40) of UK TT firms, of which 60 per cent (12/20) attend as exhibitors. It is attended by *"yarn suppliers, machine suppliers, fabric manufacturers, there's fabric manufacturers in terms of physical bits of fabric* [TT firms] *but there's also quite a lot of companies who are doing the next stages* [second tier suppliers and lead customers]*"* (E-S-Weaver/Knitter-1, 2013). Techtextil is therefore the principal platform to showcase the latest textile innovation developments and provides a forum for firms to meet and engage with current and new customers, suppliers and competitors (O'Mahony, 2007).

Selection of Routines

UK TT firms have gradually adapted their innovation and production routines by being receptive to new ideas and practices (Martin and Sunley, 2006; Rigby and Essletzbichler, 1997). In their search processes, firms learn of and generate hundreds of ideas (E-M-Knitter-4). A selection process then occurs, where firms test the creation and absorption of new knowledge to the reality and capabilities of the firm (Boschma and Frenken, 2011). Through selection, firms assess which *"ideas are worth looking at"* and if any *"of them will actually become a* [new] *product* [or routine]*"* (E-M-Weaver-11, 2013). Through forces of selection and experimental learning, some of this new knowledge and information is selected, modified and becomes embedded in the adaptation of firms innovation and production routines, whilst others are selectively eliminated (Aldrich and Ruef, 2006; Malmberg and Maskell, 2010).

This selection process is determined by a complex interaction of factors including the internal environment and capability of the firm, customer interactions, changing competitive dynamics and regulatory environments. These factors are all working together in different ways, at different times, in different firms, which explains why only over half of the UK TT firms (57.5 per cent) have adapted their innovation routines to include an innovation space, testing laboratory and dedicated product development teams (Section 6.2). In this case, to implement effective co-innovation strategies, these firms have consulted and listened to their customer's when selecting what new ideas they should pursue when modifying their innovation routines (Nelson

and Winter, 1982). The different requirements and demands of firms economic relationships and market changes (E-RBV framework) condition a firms absorptive capacity to new knowledge and technological opportunities in their search and selection processes (Boschma and Frenken, 2006; Nelson and Winter, 1982).

This section has examined the adaptability of UK TT firm's routines, the capacity and ability to engage in continual processes of change (Boschma and Frenken, 2006; Martin, 2010; Schamp, 2005). An inability to adapt routines restricts firms capacity to change and may lead to a negative 'lock-in' with long-term consequences for the continued competitiveness of the firm (Martin and Sunley, 2006). It has explored how path dependent processes of an established client base and existing management team can restrict the adaptability of UK TT firm's routines. However, as firms became increasingly conscious of their routines and strategies, in response to changing competitive dynamics, over half of the firms (21/40) have employed a new management team, which have driven the adaptation of their routines.

Processes of search and selection have informed the adaptation of UK TT firm's innovation and production routines (Nelson and Winter, 1982; Simmie, 2010). Search involves organisational learning, the generation and interpretation of new information (Aldrich and Ruef, 2006), and experimental learning, the experimentation of this new knowledge to assess if ideas fit within their capabilities to modify existing routines (Essletzbichler and Rigby, 2007). UK TT firms learn internally by predominately

exploiting the embodied tacit knowledge of their employees, as well as, externally by networking with employees of different firms at industry events. Selection is the evaluation of whether to select and embed this newly acquired knowledge (Malmberg and Maskell, 2010). Firms test ideas to the reality and capabilities of the internal environment of the firm, as well as their changing competitive dynamics, regulatory environment and long-term customer relationships and interactions (Boschma and Frenken, 2011; Malmberg and Maskell, 2010).

This section provides supportive evidence that dynamic capabilities based on organisational and experimental learning may be the ultimate cause of firm adaptation (Bryson and Ronayne, 2014). Organisational learning to generate or adopt new technological developments is critical as it determines the adaptability of firms routines (Boschma and Lambooy, 1999). This further validates the importance of employee's capabilities to absorb, trial, evaluate, and generate new knowledge in the adaptation of UK TT firm's routines. The next section investigates the development of UK TT firms workforce capabilities to develop and implement adapted routines (Boschma and Martin, 2010).

6.5 Implementing Adapted Routines: Expertise and Skills

Routines are formed by individual skills, tacit (embodied and difficult to codify) and practiced (learning by doing) knowledge of workers, as well as experimental learning

or serendipitous moments within a firm (Boschma and Frenken, 2006). To adapt their innovation and production routines, UK TT firms *"needed* [their employees] *to change the way* [they worked] *and the way information* [flowed] *in the factory etc."* (N-M-Weaver-4, 2013). This highlights how firms are dependent on the capabilities of their workforce to adopt and employ new behaviour and knowledge into existing processes and practices (Penrose, 1959; Rigby and Essletzbichler, 1997). It is the collective skill set of firms, which determines their ability to stay abreast of innovative technologies emerging amongst their global competitors (Christopherson, 2011; Stam, 2010). As the amount of employees employed by the firms have reduced with automation and lean manufacturing strategies (Section 5.2), all employees are now required to be active and open in searching for better technologies, ideas and practices (Aldrich and Ruef, 2006).

Adaptation of UK TT firm's routines to implement their competitiveness strategies required the co-evolution of the workforce to new ideas and practices (Boschma and Lambooy, 1999). For 40 per cent (16/40) of firms, the adaptability to evolve existing routines was constrained by their established workforce:

> *"It's challenging to bring in outside ideas and processes which are known obviously for the better of the organisation but at the same time respect the tradition, the history and the knowledge that exists within the organisation and get that happy marriage"* (E-L-Knitter-8, 2013).

Established patterns of behaviour became a key obstacle to these firms in adapting their routines, as it limited their employee's learning capabilities to innovate or adopt new technologies (Boschma and Lambooy, 1999):

> *"Because the machinery is so old and machinery itself cannot really be modernised, my personal opinion is it's been hard for the company to modernise...* [and] *change the way it works, if your basic machinery isn't changing it's actually quite hard to get the staff to look at new things"* (E-M-Bobbinet-1, 2013).

This firm explains how their existing production routines operate from old and customary machinery, which has met its perceived modification capacity to be altered and improved. This led to their employees absorbing countless elements from their surroundings, but not actively processing the information, meaning passive absorption replaced active awareness (Aldrich and Ruef, 2006; Bryson and Ronayne, 2014). This explains how some routines can become a form of mindless or passive behaviour, in which existing procedures prevent a firm from learning and innovating (Martin, 2010; Martin and Sunley, 2010).

The internal struggle amongst the workforce for this group of 16 firms to *"implement any kind of change…"* and operate a willingness and openness to learn (Essletzbichler, 2009), is because some *"…people like change and* [others] *find change very difficult to deal with"* (E-M-Weaver/Knitter/Nonwoven-1, 2013). This group of UK TT firms implemented three different strategies to engage their employees in the adaptation of their innovation and production routines (Section 6.2 & 6.3). First, 37.5 per cent (6/16) of these firms introduced changes to their routines very slowly, in "*bite size chunks"*

(N-S-Knitter-2, 2013). For example, one firm explained how they *"have very much taken the thinking and the principles* [of lean manufacturing] *and made it manageable within* [their] *own environment… so* [when they] *start talking to people* [on the shop floor, employees don't think] *'what's* [the manager] *on about?'* [or] *'what kind of language is he speaking?'"* (E-M-[Narrow]Weaver-1, 2013).

Second, a further 37.5 per cent (6/16) of these firms developed a monetary incentive strategy to engage their shop floor employees in the routine changes, as one firm explains: *"we pay a bonus at the end of the year, 10 per cent of the profit goes to the staff to say 'look, you can get a financial benefit out of this as well'"* (E-S-Nonwoven-5, 2013). This has empowered employees with responsibility in the trajectory of their firm and enforced the message that *"if* [they] *waste material or leave lights on or if* [they do this, that and the other]*, then actually it's* [their] *money* [they're] *wasting as well"* (E-M-Weaver/Nonwoven-1, 2013).

Third, firms had to ensure they had *"the right people on the bus"* for adaptability, as *"no matter how much training* [firms] *give* [employees]*, if they haven't got the willingness to learn, it's not going to be absorbed"* (E-M-Weaver-10, 2013). In the past decade, 25 per cent (4/16) of these firms have assessed the configuration of their current workforce and in some cases have removed certain employees, which were not conducive to the adaptation of routines:

> *"We had to change and during them years* [since 2006] *I mean I had to do some kind of nasty things with certain people, getting rid of them which isn't always a great thing, because they weren't conducive with what we were trying to do, they weren't going to change so we kind of had a few redundancies here, there and everywhere and a bit of moulding to put people down the kind of route that we wanted to take… we've got a really good team here now and that's a really strong part* [of the company]*"* (E-M-[Narrow]Weaver-7, 2013).

UK TT firms have shaped or moulded the composition of their workforce to develop an effective team to implement new routines and work at an optimal level (Boschma *et al.*, 2009).

Similarly, firms have questioned *"how can we technically be competent if we don't have that skill set inside* [the company]*?"* (E-M-Nonwoven-7, 2013). To acquire specialist expertise and capabilities that they don't have within their workforce, firms have recruited and introduced new employees into the firm (Section 6.4). The integration of different types of expertise in the firm enables workers to further learn from one another and become more innovative (Bathelt and Gertler, 2005; Christopherson, 2011), as the following firm has found; this *"conjunction"* of *"fresh blood"* with *"core skills"* is the reason *"why* [they've] *been able to introduce products that have been a mix and identifying new market issues"* (E-M-Weaver/Knitter/Nonwoven-1, 2013).

Development of Workforce to Implement Adapted and New Routines

The workforces of UK TT firms are *"having to become more skilled all the time"* (N-M-Nonwoven-2, 2013). This is to ensure they have the capability to implement new routines, which revolve around their innovation and expertise competitiveness strategies (Chapter 5), as *"the products* [they] *make now are more demanding than the ones that* [they] *use to manufacture ten years ago"* (E-M-Nonwoven-3, 2013). The skill development of 37.5 per cent (15/40) of firm's employees, are informed by *"formalised training programmes"* (E-S-Knitter-5, 2013), of which 80 per cent (12/15) are trained through apprenticeships [4] and 20 per cent (3/15) through college or university learning modules. These training mechanisms provide *"the individual* [with] *a broad brush background in textiles manufacturing, …*[the familiarity] *with technologies of different textiles, as well as* [their] *own, and is sort of like the starting point* [or] *the bedrock of developing a knowledge in textile materials"* (E-M-Nonwoven-3, 2013). Another training avenue for a further 7.5 per cent (3/40) of firms is provided by their machinery and equipment suppliers located in Germany, where firms will send their employees on a course *"for a week or two"* and *"*[the equipment suppliers will] *train* [TT employees] *in how to use their machines"* (Interviewee 2, E-M-[Narrow]Weaver-7, 2013).

[4] An apprenticeship is 'a structured programme of vocational preparation, sponsored by an employer, juxtaposing part-time education with on-the-job training and work experience, leading to a recognised vocational qualification at craft or higher level, and taking at least two years to complete' (Ryan and Unwin, 2001: 100).

UK TT firms are finding that the *"training and development of the people for* [their] *types of businesses in technical textiles is difficult"* (E-M-Nonwoven-7, 2013). During the peak of the UK textile industry in the 1970s (Chapter 1), "*there was lots of supportive infrastructure, lots of places where you could go to learn about textile technologies"* (E-S-Knitter-6, 2013). Local colleges and university departments use to teach textile *"theory"* and *"technical knowledge"* (N-S-Knitter-1) through specific production courses *"for weaving technicians and weaving skills* [for example]*"* (E-M-[Narrow]Weaver-5, 2013). However, the gradual demise of the traditional textile industry in the twentieth century caused many colleges and universities about *"10 to 15 years ago,* [to get] *rid of their textiles departments and machinery"* (N-S-Knitter-1, 2012). Hence, the relatively low amount of universities with TT research departments located across the UK (Table 6.2).

A key issue is that the UK TT industry is a relatively small industry, with only 76 firms identified in the sector and 40 interviewed (Chapter 3). There is only one apprenticeship in the UK entitled 'Higher Apprenticeship in Fashion and Textiles' provided by the Huddersfield Textile Centre of Excellence (CreativeSkillset, 2015). This apprenticeship provides some form of training on TT but is shared with the fashion and clothing industry, due to the low demand from a small number of TT firms. The size of the UK TT industry does not justify an independent TT course, especially with the geographical spread of firms (Figure 4.2), which would mean there would only be a handful of employees per course, as one firm situated in Northern Ireland explains:

> *"It's not like when you use to be able to send people out for day release to the local technical college… it* [would be] *impossible for us to send somebody on day release to Manchester* [for an apprenticeship]" (E-S-Knitter-6, 2013).

Despite the fact that 30 per cent (12/40) of firms are utilising this apprenticeship, firms claim the *"real problem is the lack of apprenticeship schemes"*, which are *"misguided"* and *"only suggested by people who don't understand the industry"* (E-S-Knitter-5, 2013). This programme is inadequate for a large majority of TT manufacturers, as the technical knowledge and skills required for TT is very different to the fashion industry (Ryan and Unwin, 2001). Consequently, for over half of UK TT firms (22/40) *"any training that* [they] *are doing,* [they're] *having to do* [themselves]*"* (E-S-Knitter-6, 2013).

Firms develop the skill set of their workforce internally through succession management, and the transfer of knowledge and skills between workers (Brooke and Taylor, 2005):

> *"I'm lucky that I've still got a handful of people that are steadfast and they've been here for a long time to train these people… the only person who's had any narrow fabric qualification* [training] *is myself* [the managing director]*, I had to go to Derby* [college] *for two years to do that, so I try give what knowledge I've got to the next tier down, which is the supervisors and line managers for them to go and do the same thing"* (E-M-[Narrow]Weaver-4, 2013).

Firms utilise their older workforce, with previous experience and training attained during the heyday of textile manufacturing, to train their younger workforce (Christopherson, 2009). Firms have structured their internal development and training (E-M-[Narrow]Weaver-1), by employing their own training programme or matrix

(Ronayne, 2010), which monitors the training, circulation of different job roles and skill gaps of individual employees (E-M-[Narrow]Weaver-3).

This section has examined the importance and development of UK TT firm's employee's capabilities to successfully implement new and adapted routines. It has further contributed evidence on how the established workforces of UK TT firms, has been an adaptability barrier for 40 per cent (16/40) of firms. To resolve this, 37.5 per cent (6/16) of firms introduced routine changes very slowly and a further 37.5 per cent (6/16) of firms provided a monetary bonus as an incentive to engage their employees in routine change. The remaining 25 per cent (4/16) of these firms moulded the composition of their workforce, which involved making certain employees redundant and recruiting new employees with related but diversified expertise to increase the capabilities within the firm, to implement new routines.

UK TT firms have and continue to develop the skill set of their workforces to adapt and implement their innovation and production routines. However, firms have found it increasingly difficult to train and develop their employees due to belonging to a relatively small industry. There is one apprenticeship that is somewhat relevant to UK TT firms, which is shared with the fashion and clothing industry, and is utilised by 30 per cent (12/40) of firms. A further 15 per cent (6/40) of firms develop their workforce through formalised training programmes provided by local colleges, university departments or equipment suppliers. The remaining 55 per cent (22/40) of firms

develop the skill set of their workforce internally through succession management. This section has therefore highlighted how the capabilities of employees and the adaptation of routines co-evolve (Boschma and Lambooy, 1999). It emphasises how the absorptive capacity to organisational learning and the implementation of adapted routines, is determined by the collective capabilities of UK TT firm's workforces (Boschma and Frenken, 2006; Rigby and Essletzbichler, 1997).

6.6 Understanding Routine Adaptation with the E-RBV Framework

Previous chapters have contributed an understanding to the evolution of UK TT firms, by employing the E-RBV framework in context to the UK TT industry. These chapters have identified UK TT firm's resources, capabilities, path dependency characteristics and external economic environment (Chapter 4) and their sources of firm-based competitiveness related to cost-, place-, innovation-, and service-based competitiveness strategies (Chapter 5). This chapter has contributed another layer to advancing the TT E-RBV framework, by examining the next evolution process, the development of variety in the adaptation of UK TT firm's innovation and production routines (Figure 6.2).

Examination into the adaptation of UK TT firm's routines has modified this section of the framework, as well as adding further firm-specific resources, capabilities and external economic environment factors (Figure 6.2). It has identified the different

processes and different factors within these processes, which work together and interact in different ways at different times, to inform the modification of existing and introduction of new routines. This is explained by different groups of UK TT firms introducing different changes within their innovation and production routines. A significant finding of this chapter was that only 57.5 per cent (23/40) of firms have adapted their innovation routines, to include formal procedures for product development and co-innovation processes with cross-functional teams or 'PODs'. How firms have designed and use their innovation spaces differ, with E-M-Weaver/Knitter/Nonwoven-1 being a novel example (Figure 6.1). Further, not all of the firms of this entire group (21/23) have introduced new R&D and quality control laboratories.

Equally, all the UK TT firms interviewed have adapted their production routines, but the changes, likewise to their innovation routines, differ between the firms. All the firms have introduced flexible and responsive working practices, which include comprehensive planning schedules, transparency of information, automation of labour-intensive processes and the engagement and multi-skilling of employees (Figure 6.2). However, only 70 per cent (28/40) have assessed their current physical production processes and engaged in the re-organisation of their shop floors. Further, 57.5 per cent (23/40) of firms that produce accredited and certified products, have implemented additional changes related to advanced and traceable procedures of

quality assurance, documentation, equipment maintenance and up-skilling of their workforce.

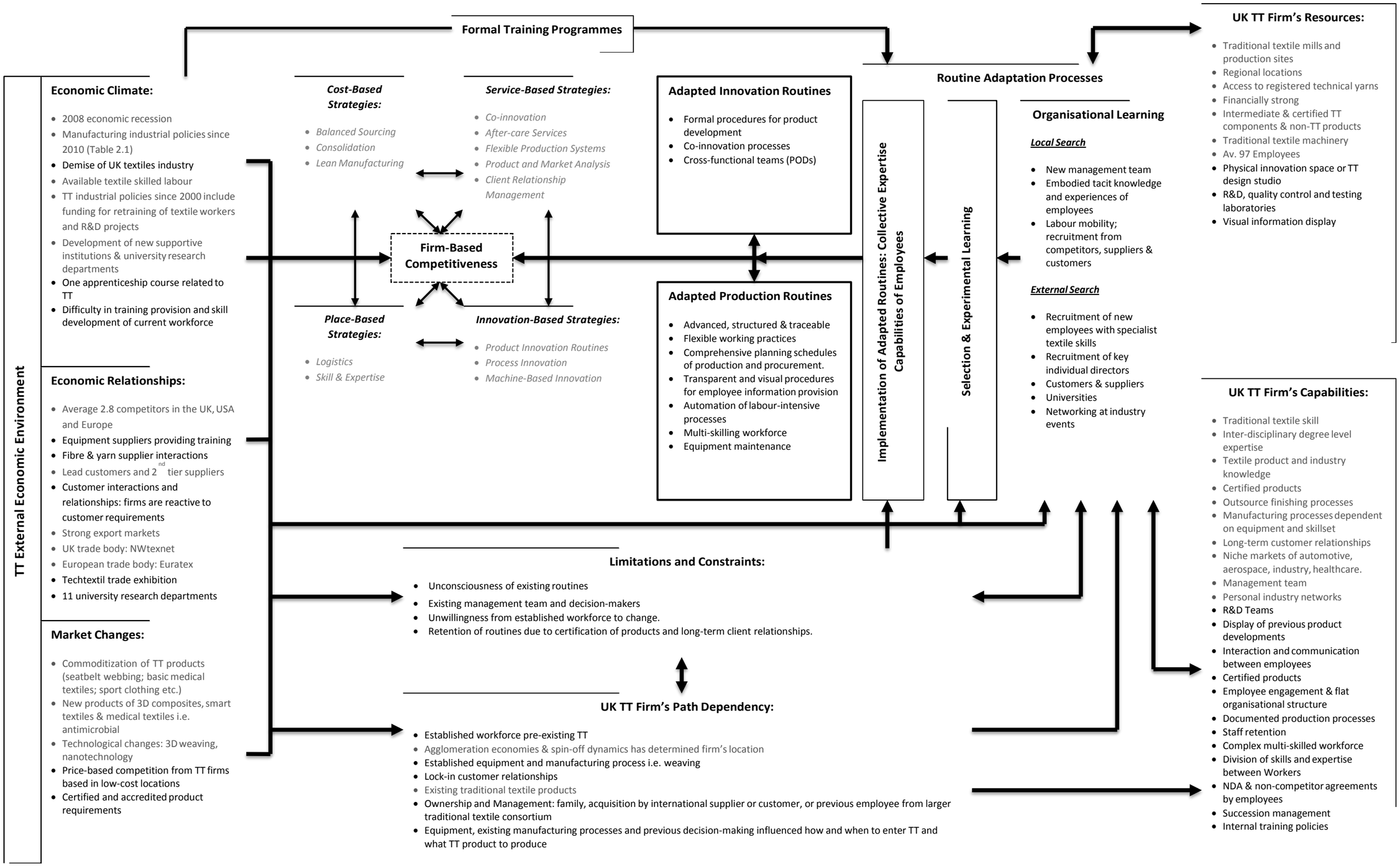
The adaptation of UK TT firm's innovation and production routines first involved search processes of organisational learning, to absorb and generate new information and knowledge (Aldrich and Ruef, 2006). Firms learn internally through their own employees and externally by the recruitment of mobile labour (Boschma *et al.*, 2009). Current employees have embodied tacit knowledge and experience of the firm, whilst new employees bring further expertise and specialist skills. This has provided firms with dynamic capabilities to learn and adopt new emerging technologies and develop new ideas and practices (Laursen and Salter, 2006; Maskell and Malmberg, 1999a). The second adaptation process involved selection, the evaluation of which newly acquired knowledge firms will select and embed into their existing routines (Malmberg and Maskell, 2010). Selection involves experimental learning, the experimentation of implementing ideas to the resources, capabilities and path dependencies of the internal environment of the firm, as well as their competitive dynamics, regulatory environment and long-term customer relationships (Boschma and Frenken, 2011; Essletzbichler and Rigby, 2007).

An inability to adapt routines restricts firms capacity to engage in continual processes of change and may lead to a negative 'lock-in', with long-term consequences for the continued competitiveness of the firm (Martin and Sunley, 2006). Adaptation

processes can become limited and constrained by a firm's path dependency of locked-in situations. This includes established patterns of sub-conscious and passive behaviour, an established workforce with low learning capabilities and absorptive capacity or willingness to change, as well as an established client base, product portfolio, product certification and existing management team (Figure 6.2). Most firms overcame these adaptability limitations by becoming increasing conscious of their routines, employing a new management team and introducing changes slowly with enticing strategies to engage their employees in change (Malmberg and Maskell, 2010; Nelson and Winter, 1982). However, an established client base of repeatable and certified products partly explains why 42.5 per cent (17/40) of UK TT firms have not implemented changes to their innovation routines outlined in Section 6.2.

The selection of new routines are defined by external market forces and changing competitive dynamics to the firm, whereas implementation of new routines is reliant on the internal capabilities of their workforce (Aldrich and Ruef, 2006; Rigby and Essletzbichler, 1997). To adapt and implement new innovation and production routines, firms have relied on manipulating and shaping the dynamic capabilities of their workforces (Bryson and Ronayne, 2014). This emphasises a key finding of how there are co-evolution synergies between the capabilities of UK TT firm's employees and the adaptability of their routines.

Figure 6.2: TT E-RBV Framework: Adaptation of Innovation and Production Routines



6.7 Summary

This chapter has examined the adaptation of UK TT firm's innovation and production routines (Research Objective 3). These two types of routines have adapted to accommodate and implement firm's competitiveness strategies explored in Chapter 5, which are customer and service focused, and centred upon innovative behaviour (Boschma and Frenken, 2006; Bryson and Taylor, 2010). There is variation in the adaptation of UK TT firm's routines, with more than one approach to implement a similar outcome of competitiveness strategies. This is because routines are process oriented, firms develop distinctive capabilities from firm-specific resources (E-RBV Framework), which is influenced by their individual innovation and learning channels, as well as their relationships beyond the firm with other actors.

Routines provide UK TT firms with continuity and change for inimitable competitiveness (Barney, 1991; Martin and Sunley, 2006). To sustain a positive trajectory, firms need to continually evaluate the performance and fitness of their routines in relation to changes in their external economic environments (Hoopes *et al.*, 2003; Martin, 2010). This chapter has emphasised how UK TT firm's routines are dependent on the dynamic expertise capabilities of their employees, which could be constrained by internal and external risks. The next chapter further evaluates the limitations and constraints to TT firm's routines, which may challenge the sustainability of their competitiveness strategies and manufacturing systems in the UK (Research Objective 4).

7 SUSTAINABLE COMPETITIVENESS AND EVOLUTION: ADAPTABILITY BARRIERS TO FIRMS ROUTINES

7.1 Introduction

UK TT firms have successfully adapted their innovation and production routines through their dynamic expertise capabilities, to implement customer focused and innovative competitive strategies (Chapter 6). The future of TT looks promising with an emerging generation of new products, customers and markets (Macbeth and Miln, 2012). Nevertheless, continuous flexibility and adaptability of firms is required to sustain their competitive position and a positive evolution trajectory (Hoopes *et al.*, 2003; Martin and Sunley, 2006). 'Adaptability' is the ability and reflexive capacity of firms to adapt and adjust their routines in response to changes in their external economic environment (Martin, 2010; Schamp, 2005). Adaptability can become limited and constrained by firm- and industry-specific challenges, which may undermine a firm's long-term competitiveness (Bryson *et al.*, 2008; Christopherson, 2011). The data analysis identified three barriers to growth for UK TT firms, which are a result of changes in their *"market conditions"* (E-S-Nonwoven-5): skill succession, innovation progression and infrastructural support of manufacturing in the UK (Field Notes, NWtexnet IAP Meeting, March 2012).

This chapter evaluates these limitations and constraints to UK TT firm's routines, which challenge the sustainability of a competitive TT manufacturing base in the UK (Research Objective 4). It is divided into six sections. The first section reviews the competitive pressures, which have required firms to adjust to high value-added TT markets. It examines the barriers to enter these advanced markets, as well as strategies developed by firms to recruit new customers, which requires sophisticated innovation and expertise capabilities. The second section evaluates the sustainability of skill succession in UK TT firms, the main adaptability barrier to firm's routines. The third section investigates the recent changes in the supportive infrastructure of the UK TT industry, and how this support influences the ability of firms to continue to innovate and manufacture in the UK. The fourth section builds upon these previous sections, and considers the skill succession and infrastructural support issues outlined to evaluate if the UK can sustain a TT manufacturing base. The fifth section contributes a further understanding to the previous empirical chapters by developing and finalising the E-RBV framework. The sixth and final section provides a summary to this chapter.

7.2 New Market Strategies to Changing Competitive Dynamics

UK TT firms competitive dynamics have changed in the last decade (Byrne, 2007). Firms are experiencing *"purely price-driven"* competition (E-M-[Narrow]Weaver-4) in a growing number of TT products, which are *"starting to become a commodity"* (N-L-Weaver-5) and are *"available ridiculously cheap from the Far East"* (E-S-Weaver-6). As TT products become more mature, standardised and routinised, their production

location shifts to lower labour cost locations (Section 4.6) (Byrne, 2007; Utterback and Abernathy, 1975). UK firms *"have had to completely revolutionise* [their] *business"* (E-M-Weaver-7), *"rationalise what* [they] *do"* (E-M-[Narrow]Weaver-4) and *"let some markets go, as cheap stuff comes in from China"* so they *"do not compete on* [the basis of] *price"* (E-S-Nonwoven-5, 2013).

UK TT firms have developed inimitable competitiveness strategies with their current product range (Chapter 5). Nevertheless, *"competitors are always a risk"* (N-S-Knitter-2) and *"if a big player decided to come onto* [a firm's] *turf… that would be a threat to* [them]*"* (E-S-Nonwoven-5). UK TT firms *"competitor's quality is improving hugely so* [firms argue they] *can't rest on* [their] *laurels"* (N-M-Weaver-1, 2012). Firms have been reflexive to these difficult market conditions and developed two key market strategies. The first strategy is to align themselves into multiple and diverse markets. The second response is to enter new high value-added and sophisticated TT markets to avoid price-based competition in more mature markets (Byrne, 2007).

7.2.1 Diverse Market Portfolio

The development of a diverse and multiple market portfolio has been the first purposeful strategy for 85 per cent (34/40) of UK TT firms. This has reduced the firm's dependency and reliance on the economic performance of a particular market sector:

> *"There's been a deliberate policy to get ourselves involved in as many industries as possible… so we've deliberately sort of, I suppose you could call it 'spreading your bets' as it were, so if one part of the business was affected it doesn't bring us down, we carry on, there's been certain things that have affected us over the years, but we've carried on because of this spread of both* [diverse] *industry and geographical* [markets]*"* (E-M-[Narrow]Weaver-3, 2013).

Firms are actively reducing the size of their key markets and operating in multiple markets. This is a strategy employed by firms for *"protection"* (E-M-[Narrow]Weaver-6), as when one market reduces and experiences a downturn they can rely on the sales of another market.

Nearly half of UK TT firms (19/40) produce TT components for the automotive market (Section 4.2). The 2008 economic recession *"had a significant impact upon the car industry"* and caused a noticeable *"slump in the European automotive market"* (E-L-Knitter-8, 2013); the key geographical location where UK firms automotive customers are based (Pavlínek and Ženka, 2010a). The automotive industry is a primary market for 20 per cent (8/40) of firms, which *"realised that the automotive market was not going to get any better* [after the recession]*",* hence 62.5 per cent (5/8) of this group of firms have *"had a very conscious attempt to diversify to* [multiple] *markets"* (E-S-Knitter-5, 2013). These five firms have intentionally reduced the size of the automotive sector as their key market and diversified to new markets of military, medical, sportswear, protective clothing and geotextiles. E-S-Knitter-5 have reduced their overall sales proportion derived from automotive markets from 65 per cent in 2008 to

45 per cent in 2013, replacing automotive output with growing sales in medical markets from 2 per cent in 2010 to 15 per cent in 2013.

There are two different but related approaches between the firms, first, market diversification and second, cost control, which demonstrates there is not one solution to the changing competitive dynamics of the UK TT industry. The remaining three firms that operate in the automotive industry as their key market, with N-L-Weaver-5 producing only airbag components and N-M-[Narrow]Weaver-2 specialising in seatbelt webbing, are focusing on cost management strategies of lean manufacturing procedures (Section 5.2.2). In automotive markets, *"everything is about price"* (E-L-Knitter-8, 2013) and customers expect TT firms to operate to *"phenomenally low* [profit] *margins"* (N-M-Nonwoven-2, 2013). Significantly, it is becoming increasing difficult to compete on non-price-based strategies in this market, as *"it's a given that* [firms] *will meet the quality standard* [and] *will deliver on time"* (E-L-Knitter-8, 2013). This is a substantial risk facing these firms, as the *"price pressure* [is] *massive, intense, relentless* [and] *never-ending…* [with firms] *having to give 5 per cent down every year, year on year"* (E-S-Knitter-5, 2013). These firms in particular will experience potentially crippling price-based competition, as new competitors located in low-cost locations enter international automotive markets. Struggle, the underlying selection pressures that increase firm mortality rates (Aldrich and Ruef, 2006), will challenge the survival of these companies once maximum production efficiency is reached at their high-cost UK manufacturing sites. For N-L-Weaver-5 *"if the business stops delivering the*

expected improvement [in productivity]*, then sooner or later* [the head office] *will decide maybe that* [the UK site has] *run its course and look elsewhere… and open up a facility like this in China".* This highlights that even with employing strong competitiveness strategies (Chapter 5), specialisation in mature TT markets with standardised products and not adapting to a diverse and broader market portfolio could become an underlying risk to these three firm's sustainable evolution.

Firms operating in mature markets, especially the automotive industry, are experiencing their customers increasingly sourcing TT components from low-cost production locations, which are at close proximity to the production of the end product (Dicken, 2011; Gereffi, 2005). This means *"the UK* [market] *cannot sustain a viable TT company"* as mature TT markets move offshore to low-cost locations. If firms want *"to grow and still be here in twenty years it has* [to be] *export all the way"* (E-M-Nonwoven-7, 2013). UK TT firms (39/40) have been influenced and experienced pull factors by their clients, which have decentralised their production systems to low-cost locations, to adopt an international focus. Firms have widened their market portfolio by developing a growing market share in an average of forty export markets (Alliance, 2015; Foresight, 2013). Between 1989 and 2009, four firms received the 'Queens Award for International Trade' for outstanding achievement in a substantial increase and continuous growth for three years in overseas earnings (GOV.UK, 2015b). Significantly, E-S-Knitter-5 increased its overall export sales by 66 per cent between 2006 and 2008 (DerbyTelegraph, 2009).

Export markets including Germany, France, Spain and Scandinavia, have *"a lot of business there, so there's a lot to attack,* [but] *it's whether* [firms] *have the capabilities to be able to do it"* (E-M-[Narrow]Weaver-7, 2013). The *"capabilities"* required by UK TT firms to *"move into export markets"* (E-S-Knitter-7, 2013) includes having "*somebody on the ground there that* [the firm] *can work with"* (E-M-Weaver/Nonwoven-2, 2013) and *"can get in the car and visit* [customers] *and sort issues out"* (E-M-[Narrow]Weaver-5, 2013):

> *"I think exporting, you really need to have good agents on the ground, an agent who is on the ground, who knows the customers, and spends his time building up relationships, finding out what they want. To do it from here* [the UK]*, it doesn't really work and going out there once a year or twice a year* [to visit customers]*, it doesn't work*" (E-S-Knitter-7, 2013).

To recruit customers in export markets and manage client-based relationships from the UK, 52.5 per cent (21/40) of firms have built up a *"network of* [sales] *agents"* (E-M-Weaver/Nonwoven-2, 2013). These firms have employed multiple agents in some countries to work with customers in specific markets, these agents have experience and technical knowledge on a particular industry (E-M-[Narrow]Weaver-3). An international network of expertise enables firms to successfully recruit sophisticated and advanced TT customers in new export markets (Byrne, 2007). This is because the production of higher value-added TT components has changed the nature of the relationship between the producer and consumer. The development of TT is dependent on the close proximity of the producer and consumer for regular face-to-face communication and complex interactions in co-innovation meetings (Chapter 5).

The remaining 18 firms manage their export sales from the UK, and do not have an international sales or technical team based in targeted export countries. This group of firms may struggle to enter high value-added markets outside of the UK. Especially, because *"in the field of TT, there are good German, French, and Italian companies out there and as a result* [customers in Europe] *can source what they're looking for domestically"* (E-M-[Narrow]Weaver-1, 2013). This could result in these firms eventually being undermined by price-based competition in export markets as they compete on TT products, which are becoming standardised. The next section examines the second market strategy of UK firms, the further adjustment into higher value-added TT markets.

7.2.2 Higher Value-Added Technical Textile Markets

Changing competitive dynamics in TT is predominately based on price in standardised and commodity type products (Chapter 5). Still, in the last decade new competitors from low-cost locations are emerging in the global marketplace with more advanced TT, for example composites (Byrne, 2007). A growing international TT industry means UK firms cannot cling on to their current TT product range as others catch up (Davis, 2011). Successful firms are letting go of producing lower value TT products and evolving to higher value-added activities by *"finding new niche markets, …*[which are] *the most obscure, the ones just coming through"* (E-M-[Narrow]Weaver-4, 2013). This second strategy of *"busily looking at trying to develop higher value products,* [and] *looking into markets where* [they] *can charge more for their products,* [and gain] *a*

greater margin" (N-M-Weaver-1, 2012), is employed by 55 per cent (22/40) of UK TT firms.

The other 45 per cent (18/40) of UK TT firms, includes seven firms, which are already *"in very textile technical, demanding areas for* [their] *products"* (E-M-Nonwoven-7, 2013) and producing medical, protective and composite TT components for higher value-added markets. This group of 45 per cent also includes a further eleven firms, which are attempting to move up the value chain in their current markets of flooring, industry and automotive via product and process innovation (Section 5.4). Products in these markets will become standardised over time once they have reached saturation in innovation capacity (Utterback and Abernathy, 1975).

Higher value-added TT markets include aerospace, military and defence, medical and healthcare, protective clothing and architecture (Quinn, 2010). These markets require UK TT firms to *"*[push] *themselves up the technology scale"* as they include *"high specification products"* with *"more advanced materials"* and *"new product development programmes"* (E-S-Knitter-5, 2013). These markets are usually safety-critical, where there are calculated and perceived risks (Chapter 5). Customers in these markets are *"risk adverse, so they like* [UK TT firms] *with* [their] *knowledge and expertise to basically take all that risk away from them"* (E-M-Nonwoven-7, 2013). TT components in safety-critical end products are required to incorporate preventative and inhibiting mechanisms to the perceived risks of each market. For example,

"product failure" in a safety harness could result in *"an injury or a fatality"* (E-M-[Narrow]Weaver-1, 2013) and a bulletproof vest has *"to do what it says it does"* as *"you don't get a second chance"* (E-M-Weaver/Nonwoven-1, 2013).

Safety-critical markets protect UK TT firms during fluctuations and from different pressures in their external economic environment. These markets have *"proved to be, relatively speaking, recession proof over the last few years"* (E-M-Weaver-7, 2013):

> *"It's been a very difficult two or three years in manufacturing and we've had our best three years in the last fifteen because if people are in a high-risk area, you cannot say you can't have any* [protective] *clothing,* [employees have] *got to have protection… if there is a perceived risk there's no excuse… a lot of our customers are in the utility sector where you've got to have gas, electric, power and* [the employees] *has got to be protected"* (E-S-Knitter-7, 2013).

TT components in advanced and safety-critical markets require *"relevant approvals for* [industry specific] *accreditation"* (E-M-Weaver-7, 2013). Certification of TT components to industry regulations of their customers can provide firms with sustainable market security and protection against competitors for up to 40 years (Section 5.4.1).

In these markets, *"the biggest single factor is the ability* [of firms] *to hit technical requirements and be able to pass the tests and be compliant"* (E-M-Weaver-8, 2013). To enter higher value-added TT markets, 72.5 per cent (29/40) of UK firms have recently adapted or are currently adjusting their innovation and production routines to

become an approved supplier (Sections 6.2 and 6.3). However, these firms stated there were specific barriers to entry:

> *"It takes a long time to get into that* [type of] *customer base… as you've got to find out who's taking* [TT products]*, find out whether or not* [a new innovation] *is even worth doing in the first place and then obviously getting in there to see them and building up a trust relationship because they've probably been buying off somebody* [else]*...* [and this can take] *months and months, if not years of trying to get into that avenue"* (E-M-[Narrow]Weaver-4, 2013).

In the past decade, UK TT firms began to adjust to these new and advanced markets in conjunction with developing their competitiveness strategies, when there were emerging signals of new competitors located in low-cost locations entering the TT industry (Byrne, 2000). To enter new TT markets, firms developed *"a good base to make sure that the next business activity* [could] *be established and pushed forward so* [they] *were not looking over a cliff* [when faced by these new competitors]*"* (E-M-[Narrow]Weaver-1, 2013).

Firms have entered markets that are associated to their current skill set and knowledge base. The *"main drive into composites"* for E-M-[Narrow]Weaver-1 was because they had *"proved to* [themselves that they could handle] *high-spec demanding technical engineering fibres, and be successful in handling them, so at that point carbon fibre didn't frighten* [them]*"*. UK TT firms *"have skills in* [their] *niche areas, which* [they] *can take to other industries and find attractive propositions",* and look for opportunities to take *"textiles into areas that have not been* [traditionally] *thought could be used in, in the past"* (E-M-[Narrow]Weaver-6, 2013). As firms have shown by

"replacing wood and metal" with composite TT fabrics in aerospace, defence and wind energy industries (N-M-Weaver-1). Firm's previous capabilities are enabling them to enter into more complex TT markets, as customers require firms to possess technical expertise to engage in the co-innovation of advanced TT products (Chapter 5).

Firms demonstrate their expertise and innovation capabilities at industry specific trade shows, by exhibiting *"fabrics that may or may not have an end use somewhere… to stir up some ideas and see where there might be more potential for* [TT, which] *might give* [new customers] *a solution to a problem they've got"* (N-S-Knitter-2, 2013). Once firms have established a relationship with a customer in a new advanced TT market, they rely on developing a *"textile solution"* reputation (E-M-[Narrow]Weaver-1) and recommendations from these new customers to recruit further customers. Referrals can be *"word of mouth"* (N-S-Knitter-1) or through labour mobility when *"people move jobs, as quite often they take* [a firm's] *contact with them to their new job"* (E-S-Weaver/Knitter-1, 2013).

UK firms have become recognised as *"leading brands"* in the field of TT (E-M-[Narrow]Weaver-6) due to receiving various innovation awards for their developments of high value-added fabrics. Five of the firms interviewed have received the Queen's Award for Enterprise in Innovation (GOV.UK, 2015b). This is awarded to firms for an outstanding or continuous innovation (product or process), which has resulted in a substantial improvement in business performance and commercial success (GOV.UK,

2015b). E-M-[Narrow]Weaver-6 received a Queen's Award for *"coming up with an innovative* [textile] *solution"* that provides protection to armoured military vehicles against Rocket Propelled Grenades (RPG) attacks. This firm took their *"net making skills*" and ability to *"make to extremely high tolerances"* from their experiences of working in the aerospace market to enter the defence market. Further firms have been issued international awards by leading global suppliers DuPont for innovation advancement in flame resistant fabrics (E-M-Weaver-10), and trade bodies including the Textile Institute (E-S-Knitter-5) (TI, 2015), as well as international trade shows: JEC Composites Organisation (N-M-Weaver-1) (JEC, 2015) and Techtextil (Techtextil, 2015a), for TT product advancement and innovations. One firm was even *"approached* [in 2005] *by a number of museums in the world"* to exhibit a key TT innovation they had developed (E-M-[Narrow]Weaver-3, 2013).

This section further explores the importance of UK TT firm's expertise and innovation capabilities to adjust and adapt their market positions to changes in their competitive dynamics (Chapter 6). Over a quarter of firms (11/40) are struggling to move up the TT value chain and enter advanced markets. This is due to these firms reaching an optimum capacity in their innovation efforts, as their TT products become standardised in their mature markets of flooring, industry and automotive (Christopherson, 2011). This could cause firms to become locked-in to their current product range within the next decade:

> *"We shouldn't be so arrogant to think that because we are technologically advanced now that these guys in Asia, Thailand or Pakistan won't catch us up in 5 years, 10 years, or 15 years' time, I don't know what time scale it will be but there will be a time when there is an equilibrium where we are now in terms of our technological and their low lever, they're coming up very quickly and if we don't keep ahead of the game, we will be the same"* (E-M-Weaver-2, 2012).

Challenges and constraints to firms innovation capabilities, including the development and absorption of expertise and knowledge, could lead to lock-in: an inability of these TT firms to improve and evolve their current product range or manufacturing processes (Martin and Sunley, 2006). Low-cost competitors will eventually catch up with UK firms as they adopt the latest materials and processing technologies in TT (Byrne, 2007; Davis, 2011). Price-based competition will cause a risk of struggle and survival to 27.5 per cent (11/40) of firms once low-cost competitors have reached a technological equilibrium with the UK. To reduce the risk of becoming undermined by price-based competition, these firms need to recognise and implement solutions to their internal risks of skill and expertise shortages (Bryson and Taylor, 2010; Kalafsky, 2008). The next section examines the barriers to skill succession and the responsive strategies developed by UK TT firms to try and maintain their expertise capabilities.

7.3 Maintaining Skills and Expertise Capabilities

Manufacturing firms core competencies have become increasingly tied to their employees, as the amount of employees in the firm has reduced and those remaining have had to become more focused and active in their daily working practices (Section 6.5). A highly skilled labour force enables a firm to adopt and employ advanced

manufacturing routines and innovation procedures to develop complex products (Christopherson, 2011; Hansen *et al.*, 2013; Kalafsky, 2008). The capabilities of UK TT firm's workforces are the reason for their entry into the production of TT and their current location (Chapter 4). Their *"knowledge and technical expertise"* is their main competitive weapon (E-M-Nonwoven-3, 2013), which informs their customer and innovation focused strategies (Chapter 5) and unpins the adaptability of firm's routines (Chapter 6). Firms therefore need to ensure they maintain, improve and develop their skills and expertise capabilities through skill succession, the transfer of knowledge and skills between workers (Brooke and Taylor, 2005).

Skill succession is usually managed and organised through older members of a firm's workforce, which utilise their own experience and knowledge to train younger members (Christopherson, 2009). During the heyday of textile manufacturing, from the 1970s to the early 1990s, a "*core group of people who have worked for ten, twenty, thirty years in* [UK TT firms]*"* (N-M-Nonwoven-1, 2013) were trained in *"textile technologies"* at their local colleges (E-S-Knitter-6, 2013). Today, in the UK, there is a lack of *"formalised training programmes"* for TT workforces (E-S-Knitter-5, 2013) (Section 6.5). The older and more experienced members of a firm's workforces are important for their skill succession *"to build* [their] *own technologists"* (E-M-Weaver-10, 2013). To the extent that *"without them there, there would be no business going forward"* (E-M-[Narrow]Weaver-4, 2013), because firms would not be able to continue

to train new members of their workforce, especially not to the existing capabilities of their present workforce.

The current employee age profile for 75 per cent (30/40) of UK TT firms is rising with an *"average age, in that age bracket of 50-65"* (N-M-Weaver-1, 2012). These firms claim: *"one of the biggest challenges that we've got is this sort of demographic cliff, in terms of* we've *got some people that have been with the firm for a very long period of time but they're five to ten years away from retirement"* (N-M-Weaver-4, 2013). Firms are concerned about *"the huge knowledge and experience going out of the company"* (E-M-Weaver-7, 2013) with retirement, and specialist skills that *"over time will be harder to fill"* (E-M-Weaver-10, 2013) and firms will struggle to replace (E-S[Narrow]Weaver/Knitter-2).

The risks related to an ageing workforce are gradually increasing and will result in *"disastrous skill gaps"* in *"the next* [five to] *ten years*" (E-M-[Narrow]Weaver-1, 2013). Firms are evaluating *"how* [they] *can change* [their] *age profile"* (N-L-Weaver-5, 2013). They are putting *"succession planning in place"* and noting *"the timescales* [of] *when* [they] *need to start looking …at replacing people as they retire with younger people"* (E-M-Weaver-9, 2013). For E-M-[Narrow]Weaver-7, they have *"known* [a key individual that operates the dye process] *is going to retire for five years"*, so they have *"trained up* [another employee] *to be on the dyeing machine"*. Succession management of specific job roles and levels of expertise have different timescales (Table 7.1).

Table 7.1: Job Role and Training Timescale for Succession Management

Job Role	Responsibilities	Time in Training*
Shop Floor Operative	•Yarn preparation and tasks away from machinery	6 weeks
Shop Floor Senior Operative	•Operate machinery	6 months
Shop Floor Technician	•Repair equipment •Set up machinery •Control the production process	3 --- 4 years
Research & Technical Technician	•Research new TT fabrics and materials •Analyse previous fabric samples •Involved in product development processes	5 – 10 years

Source: Interview Data (2012 – 2013)

• *These training times are an average of the 40 firms interviewed and approximate training duration*

UK TT firms, especially weaving and knitting firms, still utilise *"traditional craft"* skills (E-S-Weaver-6), as the manufacturing processes are *"very hands-on"* (N-S-Knitter-1). Skill succession does not involve just training an individual in a specific job role. It requires the individual to develop their own experience and learn through trial and error, as most roles on the shop floor are a *"learnt skill"* (N-M-Nonwoven-2, 2013):

> *"Anybody can babysit a machine,* [but] *to understand if the product is ok that's coming off* [the machine]*, what's gone into making that product, what can go wrong with that product and to fix that product, is a totally different kettle of fish to babysitting a machine"* (E-M-[Narrow]Weaver-4, 2013).

To develop the competency of an employee in a particular skill can take different timeframes and *"it all depends on the employee"* as one firm explains: *"… a good guy will learn in 6 months, but we've got people here who've been here two years and can only do a few of the essential skills"* (N-M-Nonwoven-2, 2013). Firms have to *"plan accordingly"* (E-M-[Narrow]Weaver-1), *"so that* [they've] *got time to grow* [new

employees]*, such that when* [a role retires, they've] *got other people to fill* [that] *position*" (N-M-Weaver-4, 2013).

Despite succession management efforts, structural factors that include 'the requirements of new skills in the workplace, perceptions of manufacturing employment and a decline in apprenticeships' (Bryson *et al.*, 2008: 183), are becoming critical barriers to skill succession. These barriers will instigate significant skill shortages, 'when there are not enough people available with the skills needed to do the jobs which need to be done' (Green and Ashton, 1992: 287). For manufacturing firms in developed market economies, 'missing a crucial element' such as skills (Kalafsky, 2008: 248) will result in 'erosion from below' (Bryson, 2011). Skill shortages for UK TT firms would undermine their competitiveness strategies that are based on their expertise capabilities (Bryson *et al.*, 2008; Lowe, 2013), as well as result in lock-in from their inability to adapt their routines and evolve to advanced and higher value-added TT processes (Chapter 6). This will lead to a struggle in their competitiveness, business growth and ultimately survival (Aldrich and Ruef, 2006; Khan and Coventry, 2008). With this in mind, the next section evaluates the current skill shortages of UK TT firms.

7.3.1 Skill Shortages: Shop Floor Technicians and Research Technologists

Skills are the 'capabilities and expertise in a particular occupation or activity' (Leitch, 2006: 6). The skill set of advanced manufacturing firms has become more diverse and complex (Christopherson and Clark, 2007). Firms now require interdisciplinary skills of the individual, as well as diverse skill sets between individuals for multi-disciplinary teams, to optimise business performance for different markets and at different stages of product and service life cycles (Foresight, 2013: 181). Skills include a blend of specific technical skills, generic skills of team working, communication and commercial awareness, basic skills of literacy, numeracy and ICT, and soft interpersonal skills of social and behavioural attributes for working with customers (Foresight, 2013; Leitch, 2006). Significantly, qualifications in Science, Technology, Engineering and Mathematics (STEM) subjects are becoming critical and will continue to be so, for the performance of high technology manufacturers (NSSA, 2010).

UK TT firm's skill sets are related to the craft of producing traditional textiles, which are predominately embodied in older members of their workforce. Firms are *"starting to lose a lot of that core skill"* (E-M-[Narrow]Weaver-4, 2013), due to *"natural selection"* of employees *"either retiring or unfortunately they've died"* (E-M-Knitter-3, 2013). However, it is notable that *"the skills and attributes* [UK firms] *need to thrive in a growing industry"* such as TT, are not the same as *"the skills and attributes available in a contracting* [traditional textile] *industry"* (N-S-Knitter-1, 2012). Skill shortages are currently experienced by 80 per cent (32/40) of UK TT firms and are complex. They

include difficulties filling textile craft skills of shop-floor operatives for 87.5 per cent (28/32) of firms, as well as highly skilled positions of TT technologists for 40.6 per cent (13/32). For shop floor operatives, weavers and knitters, UK TT firms are implementing succession management strategies (Section 7.3). As firms move into more advanced, innovative and high value-added TT processes, *"the life blood of* [the] *companies* [is their] *technical knowledge* [and analysis]*",* which firms claim are *"the harder vacancies to fill"* (N-M-Weaver-4, 2013). The next two sections examine the skill succession barriers to both types of UK TT firms skill sets.

7.3.2 Skill Shortages 1: Skilled and Entry-Level Operatives

Recruitment for shop floor operatives has been a challenge for UK TT firms since *"the sort of 1980s onwards where people left the* [textile] *industry,* [and] *there wasn't the same kind of level of influx of new blood and youth"* (E-M-Weaver-8, 2013). Firms *"in an ideal world want* [to recruit] *somebody who's already got the skill set and* [they] *just put them straight into a job"* (E-M-Weaver-7, 2013). However, experienced and trained textile weavers, knitters and technicians are part of a *"lost generation and a half"* (E-M-Weaver-8). As the UK *"textile industry locally disappeared* [over] *fifteen years ago",* firms are discovering *"there aren't any* [skilled textile] *people left, they've gone somewhere else* [and] *they're doing something else"* (E-M-[Narrow]Weaver-1, 2013). One firm stated: *"we would relish the fact that we could get weavers or technicians, we just can't get them, you can advertise for them locally, or you can advertise on a wider scale, you won't get them"* (E-M-[Narrow]Weaver-4, 2013).

Since its peak in 1973, the UK textile industry has gradually contracted from firm closures, M&As, and the decentralisation of organisations to low-cost locations (Chapter 1). This has meant *"a lot of people who worked in* [the] *industry for generations, have been hurt by its demise and struggle"* (Telephone Conversation with Industry Expert, 2012). As textile firms closed, *"people have been made redundant* [and] *they've sort of said they're not coming back into textiles again"* (E-S-Weaver-6, 2013). In the past, UK TT firms *"benefitted from the demise of the rest of the textile industry"* (E-S-Knitter-5, 2013) by *"picking up people who have textile skills"* as local companies shut down and moved *"all their production out to China"* (N-M-Weaver-1, 2012). In recent years, weaving firms have been *"picking up* [labour] *from carpet companies"* (N-M-Weaver-1, 2012). For example, E-M-Bobbinet-1 recruited two redundant employees from Axminster carpets when they went into administration in February 2013 (Bryson and Ronayne, 2014), because *"they're used to a weaving machine,* [and] *bobbinet is actually classed as weaving"*.

Recruitment from recently closed firms within the same sector (Bryson *et al.*, 2008) is a short-term and unsustainable solution to skill shortages, as *"the people that* [firms] *have taken on are in the mid-age to older age* [range]*"* (E-M-Weaver-9, 2013). These new employees become part of the ageing cohort of firm's workforces. Significantly, recruitment from closed firms has become increasingly difficult, as *"there were more places shutting down a while ago than there is now"* (N-M-Weaver-1, 2012). Firms are

struggling to *"just find somebody with experience"* (E-M-Knitter-4, 2013) as *"a lot of the skills are disappearing"* (E-S-Knitter-7, 2013).

In response to their skill shortages, UK firms have attempted 'industry poaching' and recruiting from TT competitors. However, *"it's difficult"* because *"there's not many* [TT companies in the UK]*"* and firms are *"also spread geographically"* (N-M-Weaver-4, 2013). Firms located outside of *"the foothills of the Pennines"* (N-M-Weaver-1, 2012) that border the North West of England, where the largest agglomeration of TT firms are based (Figure 4.2), do *"not* [have] *a pool of expertise labour around* [them]*"* (E-M-Weaver-7, 2013). Labour is spatially inflexible and difficult to move or obtain from another location (Pickles and Smith, 2011; Storper and Walker, 1983), because individuals *"want to work where they live currently"* (E-M-[Narrow]Weaver-5, 2013). Textile labour is particularly immobile, as employees *"are hardly likely to move home for a job that* [has a] *typical salary of below £25,000* [and] *probably in the factory"* (E-M-Weaver-2, 2012).

In response to these recruitment challenges, firms now "*employ local people who don't know one end of a loom from another and give them the skills that they need to do the job"* (N-M-Weaver-1, 2012). Notably, 40 per cent (16/40) of UK TT firms often employ *"family members from the local area"* (E-S-Weaver-6, 2013). UK TT firm's employees provide employers with access to labour through their own personal relationship networks (Granovetter, 1983), as *"it's* [their] *own workforce who know*

somebody who's looking for a job" (E-M-[Narrow]Weaver-5, 2013). The importance of 'kinship' in providing firms with a skill base 'is a common feature of community-based industries' (Bryson *et al.*, 2008: 178). For these firms *"it naturally happens"*, employees *"find out about jobs before other people or even can pass the advertisement on, and* [then potential employees] *already know a bit about what the job involves, so being a weaver wouldn't put them off"* (N-M-Weaver-1, 2012). It is quite common for firms *"to have about two or three interconnected families on the shop floor"* (N-M-Weaver-4, 2013), and older companies to have multiple generations work for them. For example, one firm that was established in 1895, has recently recruited and *"trained up a young lad of nineteen",* who *"lives in the* [local] *village, his dad is in the company,* [and] *his granddad was in the company"* (E-M-Bobbinet-1, 2013).

Recruitment and Training Challenges

On initial reflection, shop floor shortages could be perceived as *"not such a massive concern"* (E-M-[Narrow]Weaver-7, 2013). Firms can hire entry-level and low-skilled individuals with *"no textiles background"* (E-M-Knitter-3, 2013), and train them through succession management (Section 7.3). However, there are still critical barriers to firm's skill succession strategies including the difficulties involved *"to train someone up and actually getting people to want to work* [in manufacturing]*"* (N-M-[Narrow]Weaver-2, 2013).

The first training challenge is that UK TT firms *"have to self train now,* [because] *there are no sort of courses"* (E-M-Weaver-9, 2013). The lack of formal training provision in the UK (Section 6.5) is due to the small number of TT firms, as *"there just aren't enough* [firms]*, there's no critical mass, to make anything happen"* or to support a training programme (E-M-[Narrow]Weaver-5, 2013). There are difficulties associated with 'growing your own' skill base, especially for SMEs (Ronayne, 2010). First, it is *"time-consuming"* to slow down the productivity of an experienced employee or take them off a production schedule to train a new employee (E-M-Nonwoven-7, 2013). This is associated to the second difficulty of training *"being very expensive"* (E-M-Nonwoven-7), as there is a double cost to the firm in first, recruiting and training a new employee and second, removing an experienced employee from the manufacturing processes to train the new and inexperienced employee. Furthermore firms *"haven't* [always] *had the financial resources to train"* (E-M-Weaver-7, 2013).

Third, training new employees within the company could cause firms to become locked-in to their own and existing knowledge base:

> *"My only concern with* [training on the job] *is that we become a little insular, in that we train people in what we need and they don't have that wider knowledge of other capabilities, the number of times we talk to* [our employees] *who had worked* [for other textile firms and] *have some textile experience,* [for example] *we had a particular problem 10 years ago where* [these employees] *had seen a gizmo on another loom, carpet loom or whatever that did something similar* [to this firms own looms]*, you wouldn't get that if you only had home-grown capability"* (N-M-Weaver-1, 2012).

In this example, recruitment of employees that had previously worked for a UK carpet manufacturer, introduced a modification and improvement to this firm's machinery (De Jong and von Hippel, 2009). UK TT firm's process innovations and their ability to alter and improve routines are dependent on the capabilities of their employees (Chapter 5 & 6). By training their own employees internally and independently, firms fear they will restrict the expansion of their diverse knowledge and experience base.

Shop floor operatives in particular, are trained in a firms daily production routines and could passively absorb their internal surroundings, rather than being aware and processing information (Aldrich and Ruef, 2006; Bryson and Ronayne, 2014). Firm's younger employees will only be exposed to the daily routines of their own firm. They will not have the benefit of previous knowledge or experience developed during employment with another firm, nor will they learn through external and formal training mechanisms of an apprenticeship (Boschma and Lambooy, 1999; Christopherson, 2009). This restricted learning, lack of access to external knowledge and awareness to challenge existing routines, will reduce the innovative capacity and prevent the adaptability of firms, leading to a negative and locked-in trajectory (Martin, 2010; Martin and Sunley, 2006). However, some companies prefer to *"hire young people and train them right up"* because TT firms are *"so far removed from* [traditional textiles]*, it's actually a dangerous thing"* to hire *"people with previous textiles skills"* that can be *"very set in their ways"* and unwilling to adjust and adapt routines (Section 6.5) (E-S-Weaver/Knitter-1, 2013).

The final and the most critical barrier undermining UK TT firm's skills succession strategies and training efforts is the difficulty to recruit and *"attract young people into a manufacturing environment"* (N-S-Knitter-2, 2013). Significantly, in the UK only 15 per cent of secondary age students would consider manufacturing as a career option (Livesey, 2013), as one firm asserted: *"it's not people's lifelong dream to go from school and go and work in a factory"* (E-M-[Narrow]Weaver-7, 2013). The service sector has become a highly attractive career option (Beynon, 1992; Bluestone and Harrison, 1982), as *"everybody wants to run businesses, and work on computers and* [have] *nice clean jobs"* (E-M-Weaver-9, 2013). There is a negative image associated with archaic manufacturing industries, prompting '55 per cent of young students [to] believe manufacturing to be dirty' (Livesey, 2013: 5).

For UK TT firms, textiles *"still has bad connotations in people's minds"* (N-M-Weaver-1, 2012):

> *"I think people have this misconception about textiles, it's just like when you get those programmes on telly* [historical dramas based in the nineteenth century] *about a cotton factory in Manchester and people still think that's the same way as what it is now and it's so far different to that. I watched the first five minutes of it and I just thought 'God, this is going to give the wrong impression of my industry', but that's the problem unfortunately, people have this wrong idea of it"* (N-M[Narrow]Weaver-7, 2013).

This would suggest that the contemporary image of the TT industry is strongly conditioned by the historic poor working conditions of cotton mills during the industrial revolution (Burton, 2013), and the *"shocking reputation"* of the traditional textile industry in the twentieth century (E-M-[Narrow]Weaver-1, 2013). The industry

"was feast or famine", so factories were *"flat out for six month of the year and then people would get laid off"* (E-M-[Narrow]Weaver-1, 2013). Also, as *"textile companies have disappeared from* [the local] *areas, people think 'whoa, don't touch it with a barge pole'"* (E-S-[Narrow]Weaver/Knitter-2, 2013). In response, firms have *"had a change in tact"* in recruitment for the *"same job* [by] *just taking out"* any words related to textiles (N-M-Weaver-1, 2012). This is because if firms *"put the word textile in* [an advertisement]*"* or even advertise a vacancy as a carbon fibre weaver, they *"won't get any applicants,* [but] *if* [they] *put* [it as] *a supplier of industrial reinforcements* [recruiting machine operatives working in the carbon fibre sector, then they'll] *get five hundred"* (E-M-Weaver-12, 2013).

An issue with recruiting unskilled individuals to train up in TT skills is that firms are attracting *"those that are unemployable"* (E-M-Weaver-9, 2013). In addition, firms *"haven't had many sixteen to eighteen year olds come and wanted to stay longer than six months"* (E-M-Knitter-3, 2013). This is a common trend amongst manufacturing firms in the UK, which have found 'that young people do not have basic skills and, at times, not even the motivation and self-discipline to follow through with an apprenticeship' (Freytas-Tamura, 2014: 1):

> *"The trouble is getting young people who are interested, and whereas before* [in the twentieth century when there was a formalised textile apprenticeship]*, somebody would come in and they'd be quite happy to work two to three years learning a job, young people come in and really expect no more than six months and then think they should be on with a career and on a skilled payroll, so it's quite difficult to meet people's expectations"* (E-M-Weaver/Nonwoven-1, 2013).

The work values and ethics of younger employees is significantly different to older generations (E-S-Nonwoven-6), they are 'much more impatient and willing to leave their companies for a better opportunity elsewhere' (DeLong, 2004: 37). There is a *"huge cost"* in terms of wages and time in training up employees (E-M-Nonwoven-7), so when recruiting young individuals firms assess their *"attitude* [and] *whether they will stick it, whether they're prepared to go down the training route"* (E-M-[Narrow]Weaver-3, 2013).

A final barrier to UK TT firms recruitment efforts is that as SMEs, firms are unable to pay the wages and benefits offered by larger companies (Christopherson, 2011; Christopherson and Clark, 2007). Firms state *"the money isn't fantastic for the experience and qualification that* [employees] *have got, within what they do"*, they could be *"stacking shelves and earn more"* at the local supermarket, who are *"paying more per hour than a qualified technician*" (E-M-[Narrow]Weaver-4, 2013). For E-M-Bobbinet-1, *"some of* [their] *top twist hands, who have been in the business for twenty years, are earning about £8 an hour, that's not big money when they can go and stock shelves in Tesco for £7.20"*. Firms therefore *"tend to compete actually with the likes of Tesco* [and other supermarket retailers, which are] *another major local employer"* for recruitment of potential employees from the local pool of labour (N-M-Nonwoven-1, 2013).

TT firms are *"technical businesses* [and] *very skilled. Historically,* [textiles] *hasn't been the best paid kind of work so you've got this kind of dilemma, where people are technically very skilled but they're not amongst the higher earners"* (E-M-Weaver-8, 2013). Low wages within TT firms for shop floor operatives is therefore path-dependent from the traditional textile industry. All firms within the UK TT industry have adopted a similar profit margin and regulated wage structure of the traditional textile industry (Gregory, 1982), by not paying *"dramatically above the* [national] *minimum wage"* (E-M-Knitter-3, 2013) (Table 5.2). Firms have not adapted their wages to reflect their increasing skill set, as they have become an advanced manufacturer (Foresight, 2013). However, these low wages also indicate the productivity and current economic performance of UK TT firms (Alliance, 2015), as one firm states *"it's just a market thing, if we start making the money, we can pay better wages and get the decent guys*" (N-S-Knitter-1, 2013). Increasing pressures to reduce costs and profit margins are beginning to be experienced by 82.5 per cent (33/40) of firms. These firms are either partially (22/40) or wholly (11/40) operating in TT markets, which are becoming mature and driven by price due to changes in competition (Section 7.2.2). As firms enter higher value-added TT markets that will derive a higher profit margin, the wage structure of the industry could potentially change in the future and ease this recruitment challenge.

UK TT firms have very skilled shop floor operatives *"purely because they've been* [with the firms] *for a long time"* (E-M-[Narrow]Weaver-4, 2013). The firms *"seem to be very*

good at retaining staff", with some employees working for the same company *"their entire life, as they've moved from shop floor up into the technical management side"* (N-M-Weaver-4, 2013). For TT firms, *"retaining people isn't a problem, it's getting new people to join* [them]*"* (E-M-Weaver/Nonwoven-1, 2013). Firms need to actively recruit and train new people to replace their ageing workforces (N-M-[Narrow]Weaver-2). An ageing population of experienced textile workers and challenges in recruiting young people is together reducing the available working-age population for UK TT firms (Khan and Coventry, 2008).

Skill shortages of skilled shop floor operatives is a *"double edged sword"* for firms because *"not only have* [they] *got a significant number of people in their fifties and into their sixties* [that are]*… naturally wanting to retire in the next five to ten years"* but firms are also growing and need to expand the size of their workforce (E-M-Weaver-8, 2013). If firms *"can't get people, that will be the limiting factor"* to *"how big* [they] *can grow"* (E-M-[Narrow]Weaver-7, 2013), and ultimately their ability to survive in a struggle over resources of people (Aldrich and Ruef, 2006; Bryson *et al.*, 2008; Kalafsky, 2008). Having outlined the skill succession barriers to skilled and entry-level operatives, the next section examines the skill succession barriers for UK TT firm's hard-to-fill vacancies of technologists and TT experts.

7.3.3 Skill Shortages 2: Technical Textile Technologists

UK TT firms have difficulties in attracting employees with the appropriate skills. For thirteen of the firms, *"the harder vacancies to fill are on the technical analysis side"* (N-M-Weaver-4, 2013). This includes individuals with *"TT technologist type skills"* (E-M-[Narrow]Weaver-6, 2013) and *"specialist textile knowledge"* (E-L-Knitter-8, 2013) that are *"coming out of universities"* (E-S-Weaver/Knitter-1, 2013). TT technologists understand *"the raw material, the fibre, whether it's natural or synthetic,* [and how] *to take it from* [the firm] *into a commercial product, to make it into a TT fabric"* (E-S-Knitter-7, 2013). To implement their competitiveness strategies of co-producing sophisticated TT innovations with their customers (Chapter 5) and to move into higher value-added TT markets (Section 7.2.2), UK TT firms require an increasingly skilled labour force (Christopherson and Clark, 2007):

> *"The advent of the incorporation of antimicrobials* [into medical TT products] *has brought some additional requirements, again I feel that the next ten years are going to be much more interesting, the advent of regenerative medicines* [replacement or engineering of human cells, tissues and organs]*, which are incorporated in bioactive materials, that's when we're going to start needing skills that we just don't have here"* (N-M-Nonwoven-1, 2013).

As this firm explains, these thirteen firms are searching for highly skilled TT technologists to fulfil their current skill gaps and expand their expertise capabilities, in preparation for innovative evolution of TT components as their markets grow and advance (Chapter 6). However, as firms *"fear moving forward, these people are not widely available"* (E-M-Nonwoven-7, 2013). To the extent that even if they do not have

a current vacancy, *"when* [firms] *find the correct technical people,* [they will] *try and find the space in the business to accommodate them"* (E-M-[Narrow]Weaver-1, 2013).

UK TT firms are attempting to utilise higher educational institutions as sources for highly skilled manufacturing workers (Kalafsky, 2008). Similar to the recruitment challenges for shop floor operatives, *"there aren't many* [graduates] *coming into the* [TT] *industry"* (E-S-Knitter-7, 2013). As one firm states: *"manufacturing unfortunately is not sexy for …the kids coming out of university …very few will say they want to be involved in manufacturing and it's because they're not aware of what manufacturing companies can do or can offer"* (E-M-Nonwoven-7, 2013). Recruitment of graduates is not only difficult for TT firms, but an issue experienced by firms across all sectors as 'only a quarter of engineering and technology graduates work in manufacturing six months after graduation' (Foresight, 2013: 29).

To attract graduates into the TT industry, 20 per cent (8/40) of firms have pursued Knowledge Transfer Partnerships (KTPs) with universities. KTPs are where firms have commissioned an associate (a graduate or PhD student) to assist them in a new research project or develop innovative solutions (KTP, 2015). KTPs are a UK-wide programme and enable firms to access knowledge, technology or skills of universities and further education colleges (KTP, 2015). Firms are undertaking KTPs in the anticipation that they will *"then have an opportunity to recruit the* [research student]

afterwards, so [they] *see it as a way to bring in some great sort of technical expertise"* (N-M-Weaver-4, 2013).

However, a limitation for TT firms in recruiting graduates and even pursuing KTPs in the UK, is the small number of universities that offer courses specifically related to TT (Table 6.2). General textile degrees do not include *"technical* [TT] *knowledge"* as they are focused at and limited to *"designers or buyers, at best pattern cutters*" for the garment and fashion industry (N-S-Knitter-1, 2012), while students with a STEM degree do not realise the possible career opportunities in TT. As one respondent noted: *"you can trace this* [recruitment] *problem right back to education, I mean I did an engineering degree, not once did we talk about textiles, it's steel, it's aluminium, it's plastic"* (E-S-Weaver/Knitter-1, 2013). As well as textile technologists, UK TT firms require engineering graduates for their *"engineering perspective"* to modify *"equipment which* [firms] *need to develop solutions for"* (N-M-Weaver-4, 2013), as much as for their understanding of production processes and problem-solving skills (E-S-Weaver/Knitter-1, 2013).

Firms *"don't believe* [they can] *easily recruit* [R&D type people] *certainly from within the UK"* (E-L-Knitter-8, 2013). To resolve this barrier, over half of the firms (7/13) searching for TT technologists are recruiting international students:

> *"And frankly, what we've done because the skills aren't really available in the UK… we've done a very simple thing, we've started employing more foreign*

> *nationals. So we've got a girl who's our lab manager, she's got a Master's degree in mechanical engineering in textiles from Pakistan. We've got one of our development teams who's got a Master's in TT development from France, and the French are good at this again, the Germans are as well… so we're not employing British people because they aren't available"* (E-S-Knitter-5, 2013).

Universities located outside the UK, for example RWTH Aachen University in Germany in particular (N-M-Nonwoven-2, 2013), are able to offer more graduates that have *"completed a TT degree"* (E-M-Nonwoven-7, 2013). Germany has a larger TT presence than the UK as the host for Techtextil, the largest TT trade and innovation exhibition, and with TT technology clusters of university departments, equipment manufacturers and fibre suppliers (Chapter 5). The TT industry is an evolution from the traditional textile industry (Byrne, 2000). The demise of the traditional textile industry in the UK witnessed the closure and decline of textile training courses and research departments at universities (Chapter 6), whereas other countries in western Europe adapted their university research departments alongside the transformation of their firms to TT (Hassink, 2007); significantly, UK TT main competitors are located in western Europe (Chapter 5). Recruiting international TT graduates increases the potential for firms to frequently come up against their competitors in similar TT innovations, as both UK firms and their competitors will utilise the same research foundation, which initiates the development of their technical knowledge bases.

UK TT firm's innovation capabilities are dependent on the specialist expertise of their employees (Chapter 6). To implement new innovation routines, firms need to expand their knowledge base to incorporate technologists, scientists and engineers. This

diverse skill set will enable further innovation to occur from their shop floor employees, as workers are more innovative 'in situations where they are working with people with more technical skills than they possess' (Christopherson, 2011: 5). Struggle to recruit this higher skill set will become a fundamental barrier to UK TT firm's innovation progression and could undermine their competitiveness (Bryson *et al.*, 2008). The education of skilled workers for UK TT firms, like advanced manufacturers in other sectors, is becoming more complex and moving towards a combination of employer led and higher educational training (Bryson *et al.*, 2013; Kalafsky, 2008). During the time period of this research, the UK training policy has not effectively articulated the complexity and diversity of the skill sets required by TT firms (Gore, 2005). The next section examines the reasons for this, by investigating the changes in the infrastructural and institutional support of the UK TT industry.

7.4 Technical Textile Infrastructural and Institutional Support in the UK

The innovative and advanced TT products produced by UK firms are *"miles away from what they were doing"* (E-S-Weaver/Knitter-1, 2013): felt for the slipper industry, netting and rope for the fishing industry, silk jersey fabric for lingerie, jute and linen for sacking and fabric for line shirting material, dresses and traditional woollen military uniforms (Byrne, 2000). However, the foundation and growth of the UK TT industry is associated to the traditional textile industry (Chapter 4). To establish themselves in the production of TT, firms inhabited traditional textile locations to utilise the existing pool of labour with textile craft skills and the *"supporting services* [and] *suppliers"* (N-M-

Weaver-1, 2012). Infrastructural support, *"the support and ancillary services",* as well as facilities for UK TT firms is provided by their supply base of fibre and yarn suppliers, equipment manufacturers and further processing sub-contractors for the *"dyeing and finishing"* of fabrics (E-S-Knitter-5, 2013).

However, the deindustrialisation of traditional textiles in the UK (Chapter 1) has resulted in *"the entire infrastructure to disappear, which has not been replaced"* (E-S-Nonwoven-4, 2013):

> *"I think there's only one spinning company left in the UK, so currently there is a very significant problem in terms of the infrastructure of what is left of the UK textile industry because it's diminished to such a point where, I think it's fair to say, it's become challenging to run any form of* [textile] *manufacturing operation in the UK… now* [the supply base and support services] *is still there,* [but] *it's sort of hanging on by the threads if you pardon the pun"* (E-S-Knitter-5, 2013).

The textile *"supply base"* in the UK is *"contracting"* and as a result TT firms are experiencing fundamental *"infrastructural risks"* (E-S-Knitter-6, 2013). These include *"the lack of raw materials suppliers in the UK"* (E-S-Knitter-7, 2013), almost non-existent technical, equipment and engineering service support (E-M-[Narrow]Weaver-1, 2013), and a *"lack of dyeing and finishing facilities"*, which is *"critical to the performance of TT"* (E-S-Knitter-5, 2013).

Raw Material Suppliers

In trying to stimulate a new market for themselves, raw material suppliers assisted UK firms to enter into the production of TT in the first adaptation period, by informing them of new technical developments in high performance fibres and yarns (Chapter 4). As well as supplying UK TT firms, fibre producers and yarn convertors supplied the traditional textile and garment industries. They worked for the large textile consortiums that dominated the UK textile industry in the 1970s and 1980s (Dicken, 1986), and had relationships with the leading producers of artificial fibres like DuPont (Braddock-Clarke, 2007a). These raw material suppliers were therefore intermediary suppliers between UK TT firms and chemical TNCs. As the traditional textile industry declined so did these suppliers, with the majority of UK and *"European yarn manufacturers ending about five years ago"* (N-M-[Narrow]Weaver-2, 2013).

The few suppliers remaining in the UK are *"so ridiculously expensive,* [that some firms] *can't use them"* (E-M-[Narrow]Weaver-7, 2013), whereas others are trying to utilise these suppliers for assistance in their product developments, with *"a certain element of wanting to make sure that certain expertise in the supply chain base doesn't dwindle either"* (E-M-Weaver-8, 2013). This is because the majority of UK TT firm's suppliers are now either situated in low-cost locations for standard yarns (cotton) or in Europe as business units of chemical TNCs for high-performance fibre and yarns (Chapter 4). It is more difficult for TT firms as *"a pretty small customer for these* [TNC] *suppliers"* to *"get their attention"* and engage in innovation with them, *"because* [firms are] *not*

doing big volumes, [they are] *doing little bitty parts of the yarns…* [and] *need to source all these myriads of different yarn types"* (N-M-Weaver-4, 2013). This is exemplified further by the challenge for TT firms to gain their suppliers attention to just order and source their raw materials. E-M-[Narrow]Waver-7 developed *"the ejector seat on the new Eurofighter Typhoon aircraft"* and they *"couldn't get any Kevlar off DuPont",* so they had to approach their customer *"and the Ministry of Defence who sent* [the firm] *a letter to send to DuPont that said 'supply* [this firm] *with the yarn', so they then supplied* [the firm] *with the yarn".*

Equipment Service Support

Nowadays, the UK is *"not an interesting market for the equipment* [manufacturers]*"*: those that were producing and selling weaving looms for example *"in the bad old days could sell let's say ten machines a month in the UK… now* [they] *might sell three a year"* (E-M-[Narrow]Weaver-1, 2013). There are no textile machinery manufacturers left in the UK, as *"the last builder went out of business two years ago* [based] *in Huddersfield* [West Yorkshire]*"* (E-M-Knitter-3, 2013). The closest equipment and machinery suppliers for UK TT firms are currently located in Germany, Belgium, Switzerland, Austria and Italy (Wilson, 2014), with the *"German market having the power* [as a monopoly in this market] *to charge what they want"* (E-S-Weaver/Knitter1, 2013). The equipment and *"machines* [most UK TT firms are utilising] *are very old"* (E-M-[Narrow]Weaver-3, 2013). The cost to replace a piece of equipment, especially an older type of machinery, is very expensive (Table 5.1). Weaving firms are finding that

loom builders *"want to supply* [them with not one, but] *twenty looms, and* [some] *won't build a bespoke loom for* [them] *or they will do but at a very high price, …*[which if firms] *look at the return on investment, it will take forty years to pay off"* (E-M-[Narrow]Weaver-3, 2013).

To keep their machinery and equipment running, UK TT firms have to implement *"maintenance regimes* [that] *are very strict"* (Section 6.3) (E-M-Knitter-3, 2013). However, they can no longer contract machinery builders or engineers to service and repair their equipment:

> *"We've had a real problem getting somebody who understands the interface between electronics and the components* [in the machinery] *for programme electronics, and the output in terms of what is does to a knitting machine. I mean we've searched high and low to get somebody who can come in and look at our electronic systems… it took us about a year to find* [a mechanic who's] *a freelancer, so he'll be fixing a machine in a biscuit factory and then next day he'll be here but he's got the skills to do it and he says to us he can't get anybody to do it with him"* (E-S-Weaver/Knitter-1, 2013).

Firms have *"to trawl the second hand market"* for spare parts (E-S-Weaver/Knitter-1) and have had to *"develop* [their] *own sort of network of people and skills to* [maintain and repair machinery themselves]*"* (E-M-[Narrow]Weaver-1, 2013). This includes the firms depending upon one another for technical support, *"so if N-M-Nonwoven-2 have got a problem on a machine* [they'll] *phone up* [E-M-Weaver-12] *and ask them* [to help]*, and similarly they do the same"* (N-M-Nonwoven-2, 2013). Firms have developed their own workforce (Chapter 6) and are actively trying to recruit apprentice and graduate level engineers to *"maintain equipment"* and *"work out*

different routes to keep [the machinery] *going"* (N-M-Weaver-4, 2013). However, the current recruitment limitations (Section 7.3) will cause further barriers to UK TT firm's ability to maintain their current equipment.

Dyeing and Finishing Facilities

A quarter of UK firms (10/40) *"do not have any finishing facilities on site, so they send the fabrics to an appropriate finisher"* (E-S-Weaver-6, 2013). The remaining TT firms send to specific commission contractors when they do not have the capabilities in-house, for example dyeing silk for five metre wide parachute sheets (E-M-Bobbinet-1). Nevertheless, *"the continued disintegration of the textile infrastructure" has witnessed "more companies going into liquidation* [and] *more companies closing down"* (E-S-Knitter-5, 2013) *"with the special skills like dye houses", and this has become "one of the biggest problems"* for UK TT firms (N-S-Knitter-1, 2012). For example, *"Nottingham used to have probably three or four dye houses that would work for companies like* [TT firms] *and they've all gone"* (N-S-Knitter-1, 2012).

In the case of dye houses, UK TT firms now rely on six of the firms that have their own dye and finishing facilities, and are willing to *"do some third party dyeing and finishing for other people"* (E-M-[Narrow]Weaver-1, 2013). For example E-S-Knitter-5 *"owns a dye house that does a lot of* [E-M-Knitter-4] *finishing,* [and this firm states the industry] *is very incestuous like that"* (E-M-Knitter-4, 2013). Firms trade their different

capabilities to access each other's resources, as one interviewee commented: *"I supply a* [non-TT firm] *with grades* [lingerie fabric] *that they can't make, they sell my fabric but I don't make as much money, which is fine because… I use their dyeing facilities"* (N-S-Knitter-1, 2012). Even competitors E-M-[Narrow]Weaver-1 will dye fabric for E-M-[Narrow]Weaver-5 and in return they will weave a type of TT that E-M-[Narrow]Weaver-1 cannot produce in-house. One of these firms had to acquire a dye house, as *"one of the principle suppliers that* [they] *work with went into liquidation and* [they] *had no choice but to purchase that company, so* [they've] *actually got the last dye house now within Nottingham City limits"* (E-S-Knitter-5, 2013).

However, with processing their own orders, these six firms *"will not be able to cope with dye volumes as markets grow and new products grow"*. This will *"be a* [key] *barrier*" for a quarter of UK TT firms and *"the day is going to come where* [they] *are going to have to look at* [installing or purchasing] *a dye house, which is a major investment"* (N-S-Knitter-1, 2012). Due to the shortage of dyeing and finishing facilities in the UK, 10 per cent (4/40) of firms *"have had to change the way* [they] *operate"* and now *"send fabric overseas* [mainly to Europe] *for processing"*, the product then has to be returned to the company, which increases the total production costs for these firms from the transportation (E-S-Knitter-5, 2013).

This section has discussed the infrastructural support changes of the UK TT industry and consequential challenges for firms; the next section examines the current

institutional support, the role of trade associations and universities, for the UK TT industry.

7.4.1 Institutional Support: Trade Associations and Universities

Institutions are containers of socioeconomic organisation (Amin, 2001) that can provide stability and assistance to individual or a group of firms on formal structures and informal organisational conventions (Essletzbichler and Rigby, 2007). Germany, France and Italy all have *"TT groups at a national level who promote integrated working and collaboration between companies. The* [companies] *are all connected with regional economic funds, and* [trade associations] *help to attract funding"* (E-S-Knitter-5, 2013). As a result, these countries have key TT clusters of institutional support with agglomerated specialised companies, support services and universities, which is due to these "*fairly substantial grants* [and] *that there's* [been] *a good level of* [state] *investment"* (E-S-Knitter-5, 2013).

In comparison, the UK hasn't *"got a great history of supporting* [their] *manufacturing industries"* (E-M-Weaver-10, 2013). The UK's industrial policy has not had a specific manufacturing focus over the past 30 years (Livesey, 2012b), as successive governments have promoted a neoliberal regulatory model (Chapter 2). Consequently, UK TT firms feel *"the government has written off the textiles industry, it's a sunset industry as they call it"* (E-S-Knitter-7, 2013):

> *"What happened in this country was completely different to everywhere else in Europe. Everywhere else in Europe, the technical capability and value-added processes were retained by the domestic industries, so in Italy, Germany and France, the high value-added fabric manufacturing and finishing processes were retained. I think they realised prior to us that the high-cost, low-margin activity of sewing garments together would go to* [low-cost] *locations where it becomes affordable… so they were making fabric, they were cutting fabric and sending it somewhere else to make it up, whereas in this country … we hadn't preserved the fabric manufacturing industry, but we had preserved an awful lot of people doing low margin work sat behind a sewing machine* [for the garment industry]*"* (E-M-[Narrow]Weaver-1, 2013).

Industrial policies related to textiles in the past thirty years have focused on the apparel and fashion industries (Dicken, 2007), such as the cut and sew industries of the 1980s and 1990s, which made up garments for large retail groups like M&S that *"wanted to be able to say their garments were UK manufactured"* (E-M-[Narrow]Weaver-1, 2013). Significantly, since the cease of the Multi-Fibre Agreement (MFA), the competition protection policy in 2005 (Chapter 1), *"there's been no industrial focus"* (E-S-Knitter-5, 2013) on the textile industry. The industry has been left to competitive market forces and *"in these markets"*, only *"the strongest survive"* (E-M-[Narrow]Weaver-3, 2013). Traditional textile firms in the UK have either shifted production offshore or fallen *"by the wayside"* (E-S-Weaver-6, 2013). Even firms that attempted to transform to TT or entered TT in the early 1990s are now deceased, as the 40 firms *"used to have ten to fifteen competitors twenty years ago* [when they were in the first decade of producing TT, but] *they're not there anymore"* (N-S-Knitter-1, 2012). As a result, *"the pond* [for the UK TT industry] *is incredibly small now"* (N-S-Knitter-1, 2012).

Institutional support in terms of training and research deliverables for UK TT firms is delivered through trade associations and universities. The UK has ten supportive bodies that support the UK TT industry (Table 7.2). Five are trade associations that also support the clothing and fashion industries and were encouraged in the early 2000s to provide support to UK textile firms in transforming into producers of TT (Chapter 4). In 2003, NWtexnet was commissioned to act as a textile cluster development organisation for the North West of England by the Regional Development Agency (RDA) (Appendix B). Between 2003 and 2011, this organisation was one of the main UK TT organisations, which would direct government funding to UK TT firms for training and research opportunities. In March 2012, RDAs formally closed as part of the Coalition Government's deficit reduction policies (BIS, 2012). Since 2012, NWtexnet has received less public funding and have changed their focus and support services to participate in European TT research projects and deliver the latest innovation and technological information from these projects to their member firms (NWtexnet, 2015b).

Table 7.2: Supportive Bodies Working with UK Technical Textile Firms

Geographic Scale	Organisation	Overview of Organizational Role in the Governance of UK TT Industry
International	Textile Institute	An international organisation that develops an interactive network of member firms to provide an operational framework and defines and maintains quality, particularly in regard to professional qualifications and disseminates information to members, as well as informing the government on industry related issues.
National	Skillset	The UK sector skills council that represents the fashion and textiles sector. The organisation provides a lobbying voice for employers on skills issues and training needs, representing skills needs of more than 500,000 workers.
	UKFT (UK Fashion & Textiles Association)	A UK based organisation that provides business guidance on trade and employment issues and the latest industrial news through a UK fashion and textile business network. This network includes member firms across the entire supply chain – from raw materials to retail, which interact online and at network events.
	UK Trade and Investment	A UK government support and advisory organisation that provides expertise on exporting and competing in international markets for UKJbased firms, has a coJordination role across government to establish relationships with export strategic sectors and companies and delivers sector specific expertise in the textiles and clothing sector.
	Technitex	Technitex is a consultancy organisation for the UKs technical textile and advanced materials sector, which provides services for a wide range of technical textile requirements, including research and knowledge transfer.
Regional	NWtexnet	NWtexnet is an organisation that provides support in terms of developing a regional cluster in the North west of England. It provides companies with skills and guidance through informing technical textile companies of emerging technologies.
	Textile Centre of Excellence	A regional conference, research and training facility owned by textile manufacturing companies based in Huddersfield, West Yorkshire. It provides services to manufacturing companies, which includes training and development support in diverse areas, the use of a design incubator for new fashion and textile design businesses, a technical workshop for warping and weaving operations, a research and productJtesting laboratory, a fully equipped clothing studio and a IT training suite.
	LTMA (Lancashire Textile Manufacturers' Association)	LTMA provides practical advice on any issues member firms are experiencing; is a contact for sales enquires and promotes the benefits to the regional economy of a strong and healthy textile industry.
	EMTEX (East Midlands Textiles Association Ltd	The clothing and textile trade association for the East Midlands. It provides guidance on the challenges experienced in the industry, assists individual designers, product developers, buyers and marketers to get into business, introduces new technologies and working practices to over 800 members and has a has a forecasting library to streamline design development process into profitable product and service ranges.
	STIA (Scottish Textile Industry Association)	The Scottish textile association provides access to information, events and assistance in promoting products to buyers, has regular forums on industry issues and opportunities, assists the design and manufacturing firms on the industry, and has developed the 'Textiles Scotland' brand to increase the awareness of the amount of companies involved in the Scottish Textiles and Fashion Industry and represent the industry at international events.

Source: Author's Industrial Placement Fieldwork (April 2012)

Overall, textile trade associations have less engagement with TT firms *"because the majority of the people* [working in these associations] *understand the fashion aspect of textiles"*, so events, information and training delivered by these associations *"tends to be 75 per cent fashion and 25 per cent sort of technical stuff"* (E-S-Weaver/Knitter-1, 2013). The British fashion industry contributes £26 billion to the UK's economy in comparison to an estimated £1.5 billion by the TT industry (Alliance, 2015). Manufacturers involved in the fashion industry therefore receive significantly more attention from the government, universities and trade associations.

Innovation is key for UK TT firms, it *"will save* [them]*"* (E-M-Weaver-2, 2012) because *"*[they] *cannot afford to be selling the same product in another thirty years' time, even in maybe another three years' time"* (N-M-Nonwoven-1, 2013). To maximise their innovation capabilities, it is critical for firms to link themselves with the expertise of UK academic research (Lee, 2013). UK TT firms have not had positive experiences working with universities in the past (Chapter 6). Nevertheless, some firms claim working with universities is *"something that they're trying to promote"* (E-M-[Narrow]Weaver-6, 2013), as they're *"limited by* [their] *own knowledge"* (E-S-Knitter-7, 2013) and they require further technical expertise to move up the value chain (EEF, 2013). Firms want to *"visit universities, take their technologies and convert it* [into their products]*"* (N-M-Nonwoven-1, 2013). Christopherson (2013: 10) discusses how universities could be key intermediaries for SMEs:

> 'University advocates can educate policy makers and the public about the potential of advanced manufacturing, provide technical assistance and access to cutting edge technology. They can encourage internships that foster relationships between young engineering graduates and local companies'.

In the UK TT industry, there remain key barriers to this type of university and firm collaboration. First, there are only a small number of eleven UK universities with research departments related to TT, and they are not all in close geographical proximity to UK TT firms (Table 6.2). Second, a handful of firms have recently *"tried to link up with the universities…* [but] *it's just been really difficult"* (E-S-Nonwoven-6, 2013) with one firm stating: *"they can't even reply to emails"* (E-M-Nonwoven-7, 2013). Firms need to develop a common language and open communication channels with university institutions to be able to collaborate and co-innovate (2BFUNTEX Workshop Field Notes, Croatia, 2012). Third, in *"the technical journals related to TT,* [the UK] *as a country are being significantly outclassed in terms of the research funding for TT projects particularly by the Germans,* [which] *are creating world class technologies"* (E-S-Knitter-5, 2013). This is due to a non-existent industrial policy (Livesey, 2012a), and a lack of investment as *"the spending in the UK is less than* [what] *the European's spend"* (E-M-Weaver-10, 2013), to support the R&D of the TT industry (Christopherson, 2011; DRA, 2001).

Despite the fact that UK TT firms are *"very much at the sharp end of what's going on"* with textile innovations and technological developments, firms claim they receive less attention and institutional support because they are *"low profile"* (E-S-Knitter-7, 2013). TT products are intermediate components that are *"completely hidden"* and *"actually holding together"* or reinforcing end products *"in lots of different things"* (E-M-Weaver/Nonwoven-1, 2013), for example a woven carbon fibre reinforcement of the central body of an aircraft (Bowler, 2014). A better public and political understanding needs to be developed of TT, as well as the critical role this industry plays in supporting many different advanced UK manufacturing industries, especially the aerospace industry. A lack of institutional support for UK TT firms includes disengaged trade associations, inadequate training provision (Section 6.5 and Section 7.3), and unsupported research infrastructure. This current institutional infrastructure presents firms with adaptability barriers to compete in high value-added markets (Christopherson, 2011). The next section evaluates if the UK can sustain a TT manufacturing base with firm's current skill shortages, as well as the industry's infrastructural and institutional support outlined in the previous sections of this chapter.

7.5 A Sustainable Technical Textile Manufacturing Base?

There should *"definitely be a future in TT"* for UK firms because as a sector *"it's quite innovative"* (N-S-Knitter-2, 2013). However, there are *"a number of challenges in terms of growing a business that's niche"* (E-M-Nonwoven-3, 2013). Current challenges and

future barriers include searching for and entering *"really exciting and unique"* markets (E-M-Weaver/Nonwoven-1, 2013), and getting *"some youth into* [their businesses] *to see them forward for when* [the current employees] *are all gone"* (N-S-Knitter-2, 2013). For UK TT firms, *"competition is threatening to increase"* with new competitors located in low-cost locations entering the TT market (Byrne, 2007), which will intensify firms adaptability barriers and cause *"the next few years to be more challenging than the last few"* (N-M-Nonwoven-1, 2013).

The challenges are becoming so critical that 12.5 per cent (5/40) of firms are now questioning the sustainability of a manufacturing base in the UK and claim *"it's not a feasible proposition long-term to have a TT manufacturing company based in the UK, full stop"* (E-S-Knitter-5, 2013). These firms claim: *"there will always be a requirement for people who are prepared to expand the technical merits of textile products in fabrics… it's just that the manufacturing base has changed"* (E-S-Knitter-7, 2013) with *"increasing pitfalls and risks from finite resources"* (E-S-Nonwoven-4, 2013). The response of UK TT firms has been to collaborate and support one another to sustain what is left of the industry, as one firm states: *"I want us to be successful above everything, however I also want the weaving industry in the UK to be successful"* (E-M-[Narrow]Weaver-5, 2013). Firms will *"refer work to each other, if there are things that aren't particularly suitable for* [one firm, they'll] *say to a customer, it's not for us but go and speak to* [firm x]*"* (E-S-Weaver-6, 2013). However, there are two processes of erosion to the UK TT manufacturing base. The first process is globalisation, which is

challenging firm's positions in their current TT markets (Section 7.2) and weakening their infrastructure and institutional support (Section 7.4). The second is *"the skill level disappearing"* (E-S-Knitter-7, 2013) with critical recruitment and training barriers (Section 7.3) (Bryson, 2011).

The five firms questioning the sustainability of a UK TT manufacturing base state that these processes of erosion will undermine the survival of their UK sites in five to ten years' time. In response, firms will have to be *"a UK manufacturing company who don't just operate in the UK"* (E-S-Knitter-5, 2013), and have *"a hybrid model of so much in the UK but some external"* (E-L-Knitter-8, 2013). Nevertheless, firms state they cannot afford to *"lose their manufacturing capability within the UK"* because *"eventually* [they would lose their] *design and innovation capability"* (E-M-Weaver-10, 2013), as this firm defends further:

> *"It comes back to that thing of purity of innovation, if you don't have the fundamentals of how things are put together, how things are made because you lose that manufacturing skills but you just design, that design then all becomes superficial because the real understanding, the depth of how it's made is with the people that make it…* [and] *what you're doing is giving away your technical skill"* (E-M-Weaver-10, 2013).

UK TT firms require their manufacturing capacity as they co-innovate and produce bespoke products with their customers (Christopherson, 2011), which requires a thorough prototype development process to develop the production routines and methodology for each product (Chapter 5 and 6). The *"environment for UK manufacturing is not easy, it's not easy"* (E-M-[Narrow]Weaver-1, 2013). UK TT firms

need an effective industrial policy with sustainable solutions to their adaptability barriers to maintain the operation of their manufacturing sites long-term (Bryson *et al.*, 2013; Christopherson, 2013).

UK TT firms have noticed the UK *"government seems to have got the message that supporting the wealth creating part of the economy is a good thing to do finally* [and] *that relying on financial sectors… is not perhaps the right thing given what's happened"* (E-M-[Narrow]Weaver-5, 2013). Since the 2008 economic recession, that centred around failures in the financial system, industrial policies are emerging in support of a strong manufacturing base (Livesey, 2015; Vanchan *et al.*, 2015). However, firms are cautious of these new policies targeted at manufacturing, because they feel that *"the government doesn't understand the needs of manufacturers"* (E-S-Nonwoven-4, 2013).

In consideration of the UK TT industry, an industrial policy needs to develop an understanding of the complex training needs of advanced manufacturers, which requires apprenticeship schemes, employer provided training and the supply of graduates (Bryson *et al.*, 2013; Foresight, 2013). Education institutions and qualifications need to be in sync with industry and keep pace with the specialist knowledge developed, vice versa; communications channels need to be opened for manufacturing firms to connect with research departments in universities. There needs to be support for TT research with scope created for co-innovation and to produce skilled individuals between firms and universities, this will help them achieve

collectively what they are finding difficult or impossible to do as individuals (Christopherson, 2013).

The image of manufacturing and textiles, which reveals the hidden sub-sector TT, also needs to be improved to change young people's perception of the sector and improve current recruitment issues (Alliance, 2015). Policy makers frequently 'miss what is happening in small and medium sized companies' (Christopherson, 2013: 9). A return in attention is required to the textiles sector, which was at the heart of the British industrial revolution (Deane, 1965), with further detection and exposure of the UK TT industry and it's critical interdependence to other advanced manufacturing sectors such as aerospace and healthcare. This will assist TT firms to overcome their adaptability barriers and provide them with a sustainable manufacturing base.

7.6 Key Adaptability Barriers within the E-RBV Framework

Throughout this thesis, each empirical chapter has contributed a further understanding on the processes of the E-RBV framework in context to the UK TT industry. This chapter has developed and finalised the E-RBV framework (Figure 7.1). It has modified the framework by providing further information on UK TT firm's external economic environment, path-dependent characteristics, as well as their limitations to adapting routines and developing firm-specific capabilities. It has also contributed a focus on UK TT firm's strategy changes, in this case a new market strategy (Section 7.2),

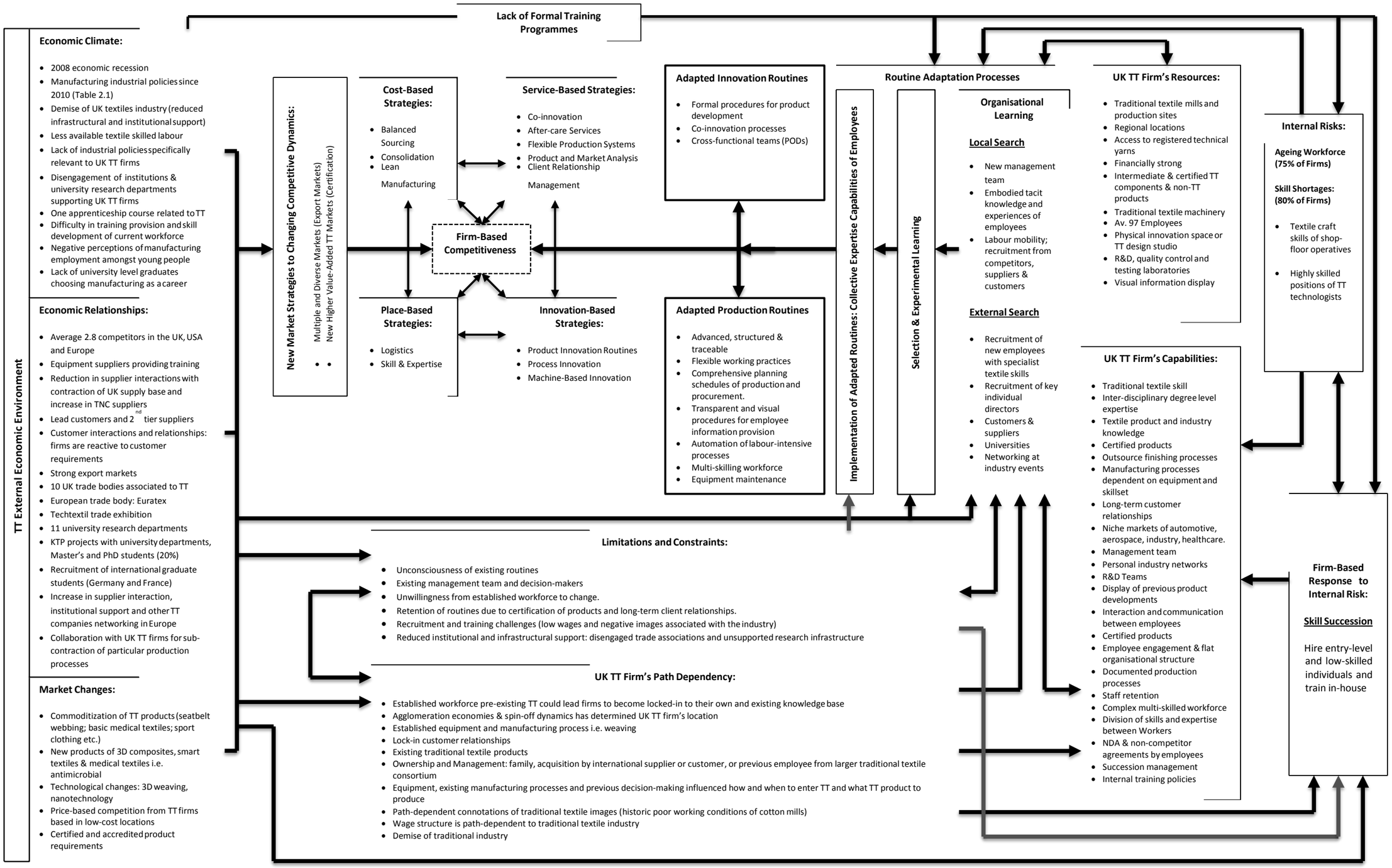
which has been informed by the current changes in firm's external economic environments that required firms to respond by developing their competitiveness strategies (Chapter 5), and in turn adapt their routines to develop and implement these strategies (Chapter 6).

This chapter has identified and contributed a further process to the E-RBV framework (Figure 7.1): critical internal risk of skill shortages, which are a key adaptability barrier (Kalafsky, 2008), as firms core competencies and competitiveness depends on the expertise of their employees (Chapter 6). The ageing of UK TT firms workforces, who embody the last of the UK's core textile craft skills, further amplifies the predicament of UK TT firms skill shortages (Bryson *et al.*, 2008; Ronayne, 2012). UK TT firms have responded through succession management efforts, but these are further undermined by significant recruitment barriers of attracting young people into a manufacturing career (Alliance, 2015; Livesey, 2013), as well as training challenges, due to the complexity of the skill set required by UK TT firms.

Figure 7.1 illustrates how the TT industry is associated to the traditional textile industry (Chapter 4) and is struggling from the consequences of the demise of this industry (Dicken, 2007). There is a lack of infrastructural and institutional support for UK TT firms (Section 7.4). However, firms have emphasised their strength and independence by adapting to more customer-focused strategies for innovation and support, rather than their suppliers to prevent becoming locked-in to their own

knowledge base (Chapter 5). Firms have also changed the way they operate and adapted their routines to focus on Europe's TT industry to develop new industrial networks and utilise their resources. Further research is therefore required to study the characteristics of the European TT industry in comparison to the UK.

Figure 7.1: Technical Textile E-RBV Framework: Adaptability Barriers to UK TT Firm's Sustainable Competitiveness and Evolution



7.7 Summary

This chapter has evaluated the limitations and constraints to UK TT firm's routines, which has the potential to undermine the sustainability of their competitive TT manufacturing base in the UK (Research Objective 4). An adaptability barrier of skill succession could restrict the evolution of firms to higher value-added markets (Section 7.2) and cause struggle amongst firms to survive and maintain their manufacturing processes in the UK (Aldrich and Ruef, 2006). Industrial support via national and regional policies, for specifically training, is required for the UK TT industry to maintain firms competitiveness in a high-cost location (Bryson *et al.*, 2013; Foresight, 2013). University and industry collaboration also needs to be nurtured to maintain innovation ecology of the TT sector, as well as develop the technical skill set required, as firms evolve further to advanced manufacturing processes and markets.

The competitiveness of UK TT firms has been emphasised throughout the empirical chapters of this thesis, and how the adaptation and evolution of UK TT firm's innovation and production routines informs the sustainability of their competitiveness. This chapter has contributed evidence to suggest that the ability of TT firms to continue along a positive trajectory is constrained by critical adaptability barriers, which need further attention by firms, trade associations and the UK government. The following chapter provides some overall conclusions to the research study and suggests further avenues of research from this initial study on the UK TT industry.

8 AN EVOLUTIONARY RESOURCE-BASED VIEW OF UK TECHNICAL TEXTILE FIRMS

> The significance of manufacturing to its region of location is a question of constant concern to geographers (Miller, 1962: 2).

8.1 An E-RBV Approach to Understanding the Evolution of Firms

Economic Geography used to be dominated by studies of manufacturing (Cohen and Zysman, 1987; Miller, 1962), but over the past thirty years, the study of manufacturing in the UK has been neglected (Chapter 2). Manufacturing still matters and plays a fundamental role in the British economy (Bryson *et al.*, 2008; Christopherson, 2011). In the twenty-first century, UK manufacturing firms have transformed and restructured, in response to new forms of competition, alterations in consumer demand and new technological developments (Bryson and Ronayne, 2014), but this evolution still remains to be explored by the social sciences and in political debates (Livesey, 2006, 2012b).

The emphasis placed by economic geography on the regional-level GPNs (Coe *et al.*, 2008; Gereffi *et al.*, 2005) has led to a relative neglect of understanding the processes of firm-level change and how firms are organised, operated and how firms are developing new forms of competitiveness for a sustainable industrial manufacturing

base. Consequently, there are key research gaps on understanding how the processes of continual innovation and adaptation have transformed manufacturing firms based in high-cost production locations, to engage in high value-added and advanced manufacturing activities (Bryson *et al.*, 2008; Christopherson, 2011; Hudson, 2010; Livesey, 2006). Firms are one of the primary building blocks of wealth generation in national economies (Taylor, 2006), understanding the performance, 'interconnection and idiosyncrasies of firms' is critical (Taylor, 2009). The micro-behaviour of firms needs to be understood as processes of continuity and change, which are based upon firm's routines, established practices, decision-making, path dependency characteristics and the wider structure of a firm's industry across time and in place and space.

The UK textile industry was at the heart of the industrial revolution (Deane, 1965; Dicken, 1986) and is, therefore, one of the oldest sectors implemented in the evolution of capitalism from the earliest times. The UK TT industry is a new variation of the British textile industry. The evolution of the UK TT industry has *involved crossing over from an existing product (textiles) into a new product type (technical textiles) and blending old machinery (weaving looms) with new processes (3D weaving)* (Chapter 4: 171). The emergence and development of the UK TT industry reflects the creation of new and sophisticated textile products and processes, which combine chemistry, physics, biology and engineering (Braddock-Clarke, 2007a; McQuaid, 2005).

This thesis identified and developed a conceptual toolkit to understand change, dynamism, evolution and the survival of UK TT firms. The RBV of the firm is one of the main approaches in the social sciences to understand firm-based competitiveness (Hoopes *et al.*, 2003). In this approach, firms consist of resources that are combined into firm-specific capabilities to develop inimitable competitiveness strategies (Barney, 1991; Bryson and Taylor, 2010). The EEG approach theorises the firm as consisting of routines that are established over time to generate value (Nelson and Winter, 1982; Penrose, 1959). The EEG perspective contributes a further explanation to the behaviour of the firm and its competitiveness, by emphasising how the firm organises its resources and capabilities into organisational routines (Boschma and Frenken, 2011; Frenken and Boschma, 2007).

This thesis has explored in the interactions between the RBV and the EEG perspectives and developed the E-RBV framework, which blends the RBV and the EEG theoretical perspectives. This new conceptual framework highlights continuity and change within firms and how firm-specific resources are fundamental to the development of routines and firm's distinctive capabilities (Figure 7.1). The E-RBV framework considers the adaptation processes of firm's routines as an evolutionary process of firm-based competitiveness, in response to changes in their external economic environment (Figure 7.1). This E-RBV integrated approach relates firm dynamics to industrial dynamics, by highlighting the inter-connections between the processes of firm-level

change (micro dynamics) to sectoral-level change (meso dynamics) in time and space (Boschma and Frenken, 2006; Boschma and Martin, 2007).

Existing studies in EEG have pursued diverse methodological approaches, 'ranging from case study research and network analysis, to duration models, simulation methods and the use of spatial econometrics' (Boschma and Martin, 2007: 545). However, these studies have predominately been focused at the regional-level, rather than at the level of the firm (Tonts *et al.*, 2014). The EEG framework needs to be supported by detailed firm-level empirical studies (Boschma and Frenken, 2011). This thesis has contributed a study at the micro-level, of how the firm is organised, operates and develops new routines to compete and learn (Aldrich and Ruef, 2006; Frenken and Boschma, 2007), by undertaking a detailed comparative analysis of 40 TT firms located across the UK.

Qualitative approaches were utilised to identify and interpret UK TT firm's routines through rich accounts of daily practices and codes of behaviour (Aldrich and Ruef, 2006; Valentine, 2005). Firm's narrative vignettes unveiled the complexity and contributed empirical evidence to evolutionary approaches and concepts (Smith, 1987). Firm's routines were identified by semi-structured interviews with the decision makers of the firms (Dunn, 2007; May, 2011; Schoenberger, 1991); the interview schedule asked interviewees to 'walk the interviewer' through the history, organisation and production processes of the company from 'when an order is received to delivery'

(Appendix E). The interaction and interdependencies between firms at the micro-level and their external economic environment at the meso-level was captured by first, firm's interpretations of their economic relationships, and second, by interviews with academic experts and industry associations.

This chapter concludes this thesis and evaluates its theoretical contribution, as well as the impact on policy. It is divided into four main sections. The next section examines the wider contribution this thesis has made to the conceptual and empirical development of evolutionary approaches. The second section explores the implications and impact on industrial policy of this research. The third section reflects on the study, evaluating the strengths and limitations of this thesis and identifies areas of further research. The fourth and final section concludes the thesis.

8.2 Technical Textile Contribution to Evolutionary Research

This thesis has investigated the adaptation and evolution of UK TT firms. Adaptation and new forms of micro-behaviour by firms resulted in industrial evolution, a renewal and restructuring, of the UK textile industry onto a new industrial path in the form of a higher value-added and innovative sub-sector, coined TT. The transformation and diversification of firms to TT was a gradual shift that began in 1942 and continued over a 70-year period to the late 1990s and is on-going. The external economic environment of UK TT firms played an important role in determining the formation of the UK TT

industry. This *included changes in the competitive dynamics of traditional textile industries, the development of a new sector that caused firms to become familiar with its existence and copy those that had entered the sector earlier, the introduction of technological developments in fibre and machinery by suppliers, and new products to the market by customers that required innovative textile components* (Chapter 4: 155).

A group of UK firms engaged in adaptation processes of organisational and experimental learning to reallocate their resources and capabilities to manufacture TT. Firm-based adaptation *required the development and employment of specific resources and capabilities, including financial strength to invest in new equipment, a highly skilled workforce to process new products on new machinery, as well as the company's owners and a management team willing to change and employ adaptation processes* (Chapter 4: 161). Combining evolutionary perspectives to the RBV of the firm provided an understanding of why the performance of UK TT firms, their degree of adaptation to TT, varied over this first adaptation period in the twentieth century. The adaptation of firms, *the process of how and when they decided to adapt to TT, has been heterogeneous and dependent on each firm's path trajectory* (Chapter 4: 156); inheritance of different routines and competencies from different parent companies, prior experience, specific skill sets and learning, all enabled firms to 'spin out' of a declining textile industry in different ways, at different times and in different places with new and innovative TT technologies.

Investigation into the history and characteristics of the UK TT industry identified two periods of adaptation, which are both a response to changing competitive dynamics. *Low-cost competitors are 'catching up', as Asia's textile industry is following a similar process to the UK in the 20th century and beginning to move up the value chain by producing TT products* (Chapter 4: 164). This has resulted in the commoditization of mature TT products and the introduction of new types of competition to the TT sector, including price-based competition, in the twenty-first century. New competitors located in low-cost locations have become a threat, particularly in the last ten years. UK TT firms have responded to low-cost producers by developing new competitiveness strategies.

UK TT firms have implemented competitiveness strategies, *which provides them with forms of inimitability, the differentiation of firms, by the promotion of difficulty or prevention in competitors attempting to imitate or copy their products and processes* (Chapter 6: 227-228). These strategies are related to exploiting advantages linked to location and connectivity. *The strategies all incorporate localised resources and capabilities of the firms including expertise, logistics and co-innovation, which all require accessibility and nearness to market, providing UK TT firms with geographical competitive advantages over competitors located in low-cost locations* (Chapter 5: 225). Furthermore, as UK TT firms are located in a high-cost location, it has been important for these firms to develop a balance of cost control mechanisms with localised and firm-based sources of competitiveness to maintain their profit levels and

manufacturing activities in the UK. These strategies are all interwoven, which provides a significant contribution to the literature on how to understand the complexity of firm-based competitiveness through examining different sources of competitiveness together, rather than focusing on one competitive strategy in isolation (Section 5.6).

UK TT firm's competitiveness is contained within their routines, which highlights the interdependent adaptation of firm's routines to the development of their competitiveness strategies. *There is variation in the adaptation of UK TT firm's routines, with more than one approach to implement a similar outcome of competitiveness strategies* (Chapter 6: 282). Adaptation involves different processes working together and interacting in different ways, at different times, to inform the modification of existing and introduction of new and idiosyncratic routines. This is because there is not a single set of routines in the industry, but micro-practices that interact and form firm-specific micro-routines. Routines are process oriented, firms have a similar set of resources of labour, equipment and products, but are developing distinctive capabilities from these resources. This is influenced by their individual innovation and learning channels, path-dependent characteristics, as well as their local-, regional-, national- and international-level relationships with their customers, suppliers, providers of manufacturing equipment, universities, training providers and trade associations.

Routines provide UK TT firms with continuity and change for inimitable competitiveness (Chapter 6: 282). There is continuity with some of the firm's routines that are related to an established client base, product portfolio and product certification, which provides these firms with a degree of certainty and stability with some of their customers. Significantly, the evolution and change of UK TT firm's routines is associated with the capabilities of their employees. The development of their employee's capabilities has enabled UK TT firm's to learn and innovate, and in doing so develop new routines or to modify existing routines, which has enabled their trajectory to be path evolving in the last ten years. Nevertheless, *the ability of TT firm's to continue along a positive trajectory is constrained by critical adaptability barriers of skill succession* (Chapter 7: 338).

Different types of labour and skill sets have been required by firms to survive over the different evolution stages of the UK textile industry. Textile firms required learnt craft-based knowledge and skills. UK TT firms still require this skill set, but also need highly skilled employees including textile technologists, chemical scientists and engineering technicians (Section 4.2). Nevertheless, UK TT firms are experiencing critical skill shortages in both textile craft-based skills and highly skilled TT technologists and engineers. *This is due to a combination of an ageing workforce, recruitment barriers of attracting young people into a manufacturing career and training challenges* (Chapter 7: 335). Skill shortages and limitations to UK TT firm's skill succession is a critical adaptability barrier (Kalafsky, 2008), as firms core competencies and competitiveness

depends on the expertise of their employees. Furthermore, *skill succession could restrict the evolution of firms to higher value-added markets and cause struggle amongst firms to survive and maintain their manufacturing processes in the UK* (Chapter 7: 338).

The E-RBV framework has been continually modified, as the key findings of this thesis have contributed new themes and processes. Unlike the conceptual E-RBV framework developed in Chapter 2 (Figure 2.5), which was theoretically informed by a critical review of the RBV and EEG literatures, the revised framework takes into account the behaviour and context of UK TT firms (Figure 7.1). The different firm-specific resources, capabilities, path-dependent characteristics and economic relationships of firms has been identified, and highlights how some of these attributes are associated to the traditional textile industry (Figure 4.9). Further evidence has specified how the four competitiveness strategies related to cost, place, innovation and services (Chapter 5), are an evolutionary process of the adaptation of UK TT firm's innovation and production routines (Figure 6.2). The different processes and different factors within UK TT firm's adaptation processes have been identified, which reveal how routines are process oriented, as processes blend and interact in different ways at different times to inform the development of varied and firm-specific routines (Chapter 6). The final version of the E-RBV framework includes a focus on the change of firm-based strategies, which is informed by the current situation in their external economic environment and stipulates the adaptation process of routines (Figure 7.1). It has also

contributed an understanding on UK TT firm's current limitations, constraints and internal risks to their distinctive capabilities and the adaptability of their routines.

The E-RBV framework provides a theoretical and empirical foundation for economic geographers and social scientists interested in firm behaviour and competitiveness to study the adaptation and evolution of firms. It starts with the premise of the firm, to understand the development of routines in firms and how firm's resources and capabilities are central to the adaptation processes of routines. Routines consist of many micro-processes that are idiosyncratic to the firm, as well as the firm's accessibility to resources and their path-dependent characteristics. There are scalar dimensions to the E-RBV framework, as an understanding of the micro-processes at the level of the firm informs the meso-processes and changes at the level of the sector and the macro-processes of an industry or region. The macro- and meso-level dynamics also inform and specify firm-level processes in time and space.

The E-RBV framework is not specific to UK TT firms investigated in this study, but one that is flexible and can be applied to other firms with consideration of the differences within each of the processes, for example different economic climates shaped by different industrial policies and sector specific processes (Figure 7.1). The E-RBV must be developed and adapted by further firm-level research, to further consider the evolving economic geographies of other industries. The next section further explores the implications and impact this thesis has on industrial policy.

8.3 An Evolutionary Technical Textile Impact on UK Industrial Policy

The past three decades 'have seen a wholesale rethinking and reworking of public policy' (Martin, 2001: 189), which provides economic geographers with major opportunities to help shape policy debates (Harvey, 1974; Peck, 1999). This thesis is relevant to policy-makers of reformed manufacturing and industrial policies in the UK. Since the 2008 economic recession, which centred upon failures in the financial system, new political debates have emerged that emphasise a rebalancing of the British economy towards manufacturing (Livesey, 2015; Vanchan *et al.*, 2015). However, as *"there has been no industrial focus"* (E-S-Knitter, 2013) in British policy for the past 30 years, it could be debated that *"the government doesn't understand the needs of manufacturers"* (E-S-Nonwoven-4, 2013).

The reformed UK industrial policy on manufacturing was considered in the formulation of this study and its research questions. A new manufacturing sector (technical textiles) that had emerged from a mature manufacturing sector (traditional textiles) was chosen, to understand the evolution of manufacturing in the twenty-first century (Livesey, 2006), as well as the changes in institutional support required by firms to inform reformed industrial policies. During the industrial placement with NWtexnet (Section 3.2.1), policy actors of the UK TT industry were engaged (Table 3.2) to question what key issues should be addressed in the formulation of the research questions (James, 2006). This thesis has focused on the micro-level of UK TT firms to inform an understanding of the meso-level of the UK TT sector, but it also provides an

evidence base to inform an understanding at the macro-level of the UK manufacturing industry to develop and improve UK industry policy (Livesey, 2015; Martin, 2001).

Key policy issues that require further attention by UK policy makers have been raised in this thesis. Various resource-based issues, including higher education and training subsidies, access to export markets and clear communication and support channels between firms and trade associations need to be addressed, as they are causing fundamental barriers to firm's routines (Chapter 7). For example, skill shortages are a major concern for UK TT firms, as well as other manufacturing firms in the twenty-first century (Khan and Coventry, 2008). Policy-makers need to articulate the skills and complex training needs of advanced manufacturers, such as TT firms. This would inform and develop an effective industrial policy (Gore, 2005), which delivers demand-led training to the requirements of employers and prioritises resources for STEM education, apprenticeships and engineering graduates (EEF/UK-IRC, 2010; Foresight, 2013).

This thesis supports and confirms other studies related to manufacturing (Bryson *et al.*, 2008; Christopherson, 2013; Kalafsky, 2008; Livesey, 2015; Lowe, 2015), which emphasise how reformed industrial policies in developed market economies should nurture and support an internationally competitive business environment for firms (EEF/UK-IRC, 2010). Policy-makers should assist in developing regions that provide 'research infrastructure, a positive business climate, amenities to attract talented

manufacturers, and pre-eminently, a skilled and creative workforce' (Christopherson and Clark, 2007: 5). To achieve this, the UK industry policy needs to incorporate an extensive range of policy measures, including regional policy, educational and training policies, as well as competition and innovation policies (Aiginger, 2007). This would support UK TT firms, and manufacturers more broadly, to become manufacturing and export powerhouses, and compete in high value-added markets (Christopherson, 2011; Foresight, 2013).

To establish policy outreach and engage with business communities, researchers need to become more promotional of their work and findings (Harvey, 1974; Martin, 2001; Peck, 1999). Wider audiences have been engaged through various modes to communicate and publicise the results of this thesis amongst policy-makers (James, 2006; Martin, 2001). First, some of the conclusions of this study have been published as a paper in a peer-reviewed journal (Publication 1), and as a chapter in an edited book: *The Handbook of Manufacturing Industries in the World Economy* (Publication 2). Second, an industry report has been produced and disseminated to the interviewees and NWtexnet. This thesis is the first major independent social science study of the UK TT industry. This report, therefore, provides some of the first insights into this new industry that is based on an old industry, as well as knowledge on the strategies other firms have developed to remain profitable and competitive.

The placement with NWtexnet, which was funded by the ESRC, has provided a valuable opportunity to facilitate the work of this trade association. The researcher has maintained a working relationship with NWtexnet as a project assistant (NWtexnet, 2015a). The results of this thesis have been communicated and disseminated to NWtexnet, which has defined and refined the UK TT industry and elaborated on the role of trade associations to ensure the sector is treated seriously. NWtexnet have learnt of the routines, micro-practices and strategies of firms, as well as the resources required by firms to inform these routines and support the development of their competitiveness strategies (Bennett, 1998; Robson and Bennett, 2000). The researcher further plans to present and disseminate the results at the next NWtexnet Industrial Advisory Board (IAB) event in April 2016. These IAB events are attended typically by representatives of BIS, academics, lead customers of the industry for example Bentley Motors and TT companies, of which 13 of the firms interviewed and a further 12 firms that refused to take part in this study are members of this trade body.

A particular area of debate within British academic culture is the dissemination of research findings to public policy to generate research impact (Harvey, 1974; Martin, 2001; Peck, 1999). This section has discussed how this thesis can be used to inform and shape the UK industrial policy, as well as the practical steps a researcher can take in order to improve the impact, reach and dissemination of their research (James, 2006). The next section reflects on the research process of this thesis, it examines its limitations and suggests opportunities for further work.

8.4 Research Process Reflections and Future Research Agenda

There are two key theoretical and empirical areas that are significant limitations to this thesis, but also provide a platform for further research. The first limitation revolves around the difficulties and constraints of studying a new industrial sector and the second limitation is the identification and substantive clarity of the EEG concepts of 'routines'. These two challenges will be examined in turn.

The UK TT Industry: A New, Hidden and Under-researched Sector

The UK TT industry is an emerging, elusive and un-researched sector and was 'hidden' from the social sciences; defining this 'sector' was difficult and negotiating access was challenging (Section 3.5). The UK TT industry has not been previously researched by social scientists resulting in definitional difficulties. The initial firm interviews revolved around in-depth conversations on the background of the firms and the TT industry. This meant that many of the themes and concepts raised were not discussed in as much detail as they would have been if the preliminary knowledge of the industry was known. A key methodological limitation of this study was the use of the single interview due to access, time and financial constraints (Section 3.5). Several strategies were developed to minimise bias from the use of the single interview, but this meant that again the researcher could not return to the field to collect further evidence to support the development of key concepts (Bazeley, 2013; Bryman, 2008; James, 2006). This has been a key learning curve for the researcher. Researchers that incorporate

company-based interviews as the main research technique in future studies, need to ensure they schedule additional time into the process of gaining access to firms and account for the flexibility required to fit around corporate schedules (Hales *et al.*, 2013).

This study is a primary basis of a new research area on the TT industry, which provides a platform for many possible directions for future research. This research has developed and contributed a new conceptual approach to the EEG field with the E-RBV framework (Figure 7.1), which could be further tested by exploring the application of the model to other sectors. This would gather additional detailed information on the evolving economic geographies of private and public sector organisations. Comparative research is needed to further reveal the idiosyncratic behaviour of individual firms, by studying the different processes captured by the framework, undertaken at different times by different firms.

Future studies could be undertaken in Europe, to study the characteristics of the European TT industry, which would provide a comparison to the EEG themes and competitive strategies that emerged from this study, as well as understand how UK firms work and interact with European firms, suppliers, customers and competitors (Section 7.4). This research has also identified an opportunity to investigate the reasons behind failed or closed UK TT firms, which did not successfully adapt or maintain their position in the emerging TT industry by interviewing ex-employer and

employees of these firms. This would provide an important historical dimension to further understanding the evolution of the UK TT industry.

This thesis has also highlighted how there is scope for future policy-related research, which could use this thesis as a foundation to inform a study on the formation and improvement of a UK industry policy. Policy-related studies could question the influence of national competition policies, import and export controls on local firms, as well as evaluate national training policies, questioning how do manufacturing firms protect and harness knowledge of an ageing workforce, especially mature and craft based industries such as textiles, to pass onto future generations. Furthermore, a policy-based examination could question how does the UK government deliver national training plans to small and heterogeneous industries, and whether it is possible for commercially sensitive knowledge of industries such as TT to be protected within group training programmes attended by employees of different firms.

Finally, to improve the preliminary understanding developed in this thesis on UK TT firms, as well as manufacturing firms more broadly, further enquiries are required to explore the direct and indirect role of trade associations and universities in driving business transformation (Bennett, 1998; Robson and Bennett, 2000). A three-month industrial placement and interviews with 11 industrial experts and 4 academics related to the UK TT industry were undertaken, however this was at the beginning of the PhD process to develop a background understanding on the UK TT industry. It would have

been useful to undertake additional interviews with these actors after the analysis of the firm-based interviews to provide further triangulation of results and rigorous empirical evidence into the relationships inside and outside of the firm.

Fuzzy EEG Theoretical and Empirical Concepts: Routines

Evolutionary approaches emphasise how firms consist of organisational routines, the organisation and management of resources and capabilities into settled and repeated patterns of behaviour (Aldrich and Ruef, 2006; Cyert and March, 1963; Nelson and Winter, 1982). The EEG field has begun to expand the definition of routines, by explaining how routines are formed by path-dependent characteristics, as well as individual skills, knowledge and experiences of workers in a firm (Boschma and Frenken, 2006, 2009; Frenken and Boschma, 2007). Routines are built up, improved upon and continually change over time through the processes of adaptation, the reallocation of firm's resources and capabilities to new organisational forms (Chakravarthy, 1982) and in response to different pressures in their external and/or internal environment (Martin and Sunley, 2010). Despite a growing number of EEG studies that touch upon the concept, routines continues to be 'fuzzy' in definition, lacking substantive clarity, empirical and explanatory rigour of how they should be conceptualised, identified and operationalised methodologically (Boschma and Frenken, 2011; Boschma and Martin, 2007; Markusen, 1999; Martin, 2001).

This thesis has contributed evidence on the adaptation processes of routines and highlighted the interdependencies between the adaptation of routines and firm-based competitiveness (E-RBV Framework). It has identified variations in one industry of firm routines and how micro-practices interact to form these firm-specific micro- routines. Routines are process oriented and are influenced by the individual firm, their learning channels, path-dependent characteristics, and relationships with actors beyond the organisation. This thesis highlights there is scope for further research to develop a more constructive definition, methodological approach and understanding of routines in the EEG literature.

Economic geographers need to identify the different organisational routines developed by firms in different sectors and the time-space distribution of these routines, as firm-based capabilities and routines vary over time and between places (Bryson and Ronayne, 2014: 486). First, the notion of routines should be incorporated more fully into the research design of future EEG studies and of firm studies in general. Second, historical time-series data on firms is needed to examine the evolution of routines, which is an outcome of historical processes (Boschma and Martin, 2007). A case study approach on individual firms would identify and conceptualise routines in detail through close observations of the firm in a specific time frame.

Routines are a key theoretical concept, but it needs further debate, interrogation and empirical evidence by economic geographers to define the different types of routines,

which would advance our understanding of firm behaviour. Future research should target and identify the micro-processes that cluster together to form a routine. This would require a multi-disciplinary approach to this research field of social scientists, engineers and operation managers to identify the micro-processes of a firm. For example, the technical details, control and coordination of micro-practices that form a routine would need to be understood and informed by manufacturing engineers.

8.5 Summary and Conclusions

The UK textile industry was at the heart of the industrial revolution of the eighteenth and nineteenth centuries (Deane, 1965; Dicken, 1986). Since its peak in 1973, production activities of some traditional textiles, especially apparel, has shifted from the UK to low-cost locations (Dicken, 2011; Gereffi, 2005; ONS, 2014). The shift in production of mature manufacturing industries has been associated with a shift in academic focus within the field of economic geography (Bluestone and Harrison, 1982; Cohen and Zysman, 1987). This study has emphasised how some firms in a mature manufacturing sector, such as traditional textiles, have engaged in adaptation and evolution processes to transform themselves into manufacturers of innovative and higher value-added products. This analysis highlights the local and firm-based aspects of economic activity rather than emphasising GPNs; routines within firms are critical for understanding firm, sector, regional and national competitiveness. Consequently, manufacturing still matters and the significance of manufacturing to the UK should be a question of constant concern to economic geographers (Miller, 1962).

This thesis has applied evolutionary approaches to the UK TT manufacturing sector and investigated the adaptation and evolution of 40 UK TT firms. It has contributed a new methodological and theoretical approach to the EEG literature to understand how the micro-behaviour of firms has been formative to the evolving economic geographies of manufacturing (Boschma and Martin, 2010). The E-RBV framework, a new conceptual framework developed (Figure 7.1), specifies the adaptation processes of firm's routines as an evolutionary process of firm-based competitiveness, in response to changes in their external economic environment. This thesis makes significant contributions to understanding firm-level change, firm-based competitiveness, the adaptation of routines and the interdependencies between the routines of the firm and their competitiveness.

This thesis provides a stimulating platform for a series of avenues for future academic and policy research. The E-RBV framework is a foundation to develop further practiced firm-based studies on the evolving economic geographies of manufacturing. This framework needs to be developed and adapted by applying it to other firms in different sectors and in different countries. Similar to Christopherson and Clark's (2007) study on the photonics industry that emerged from the optical, imaging and photographic equipment industry, this thesis has explored the evolution of a new and innovative sector (technical textiles) that has emerged from a mature manufacturing industry (traditional textiles). Further economic geography studies should engage in the change and evolution of other manufacturing sectors. In particular, the different

ways in which firms develop competitiveness strategies that blend firm- and regional-based resources and capabilities with routines that emphasise cost control with product differentiation needs to be examined (Bryson and Ronayne, 2014). This highlights that emphasis needs to be placed on the concept of routines; a more constructive definition and focus on routines would advance our understanding on the micro-behaviour of the firm, which would explain the meso-level of the sector studied, and in succession inform our understanding on the changing economic geographies of manufacturing at the macro-level.

This thesis has developed an understanding on the adaptation and evolution of the UK TT industry, by focusing on the evolutionary process of firm-based competitiveness, which specifies the adaptation of firm's routines. Routines are developed by micro-processes and practices, which build upon and engage with firm-specific resources. The UK textile industry is an established and mature industry that has continuity and change to it through the evolution and emergence of the UK TT industry. The UK TT industry has very different dimensions and characteristics, but also some association and similarities to the traditional textile industry.

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10 APPENDICES

Appendix A: Table of UK Textile SIC Codes (2007)

Appendix B: Industrial Placement Report

Appendix C: Sources and Identification Processes of UK TT Firms with References

Appendix D: Access Letter to UK TT firms & Participant Information Booklet

Appendix E: Interview Schedule

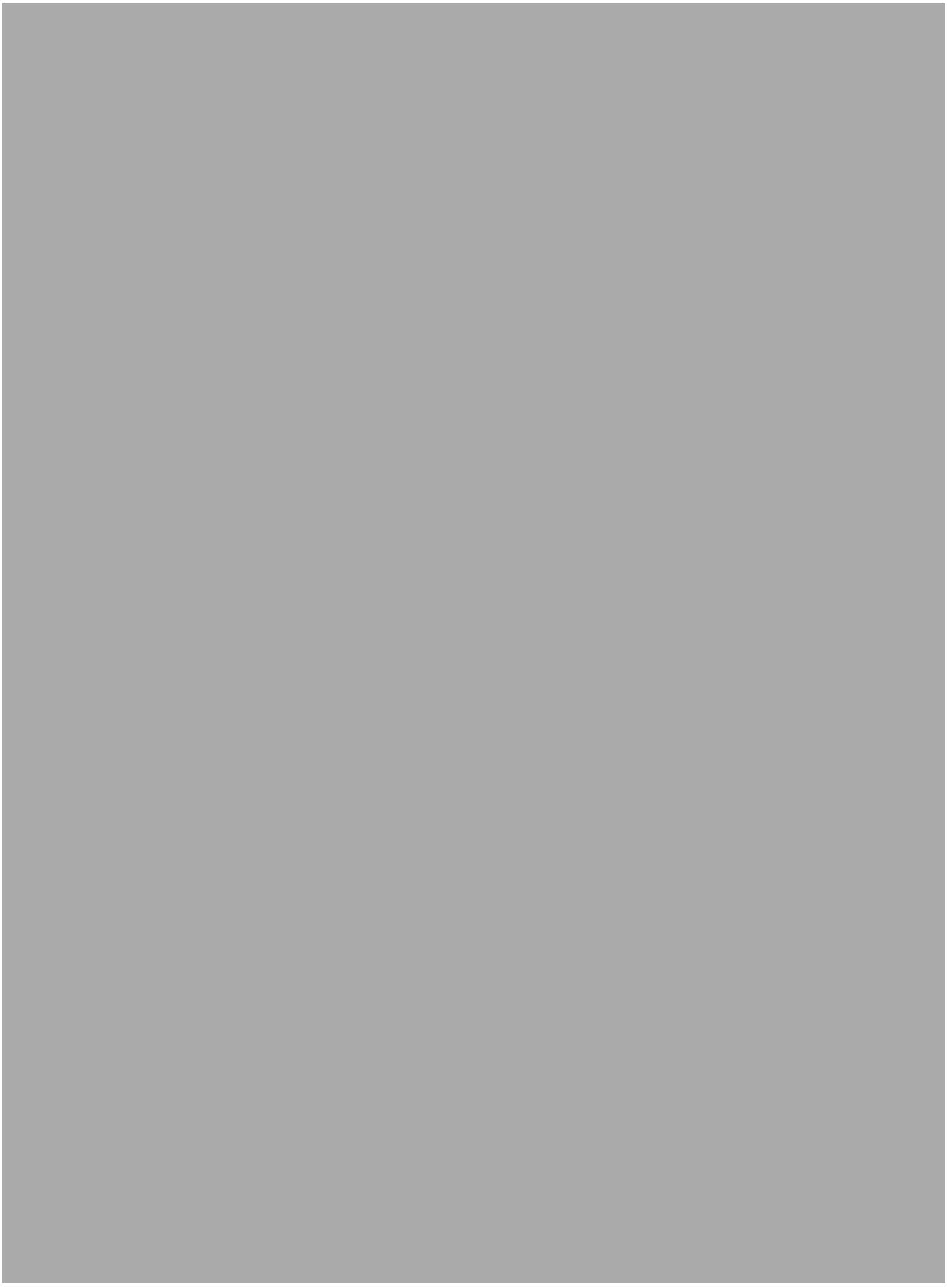
Appendix F: Interview Reflection Form Example

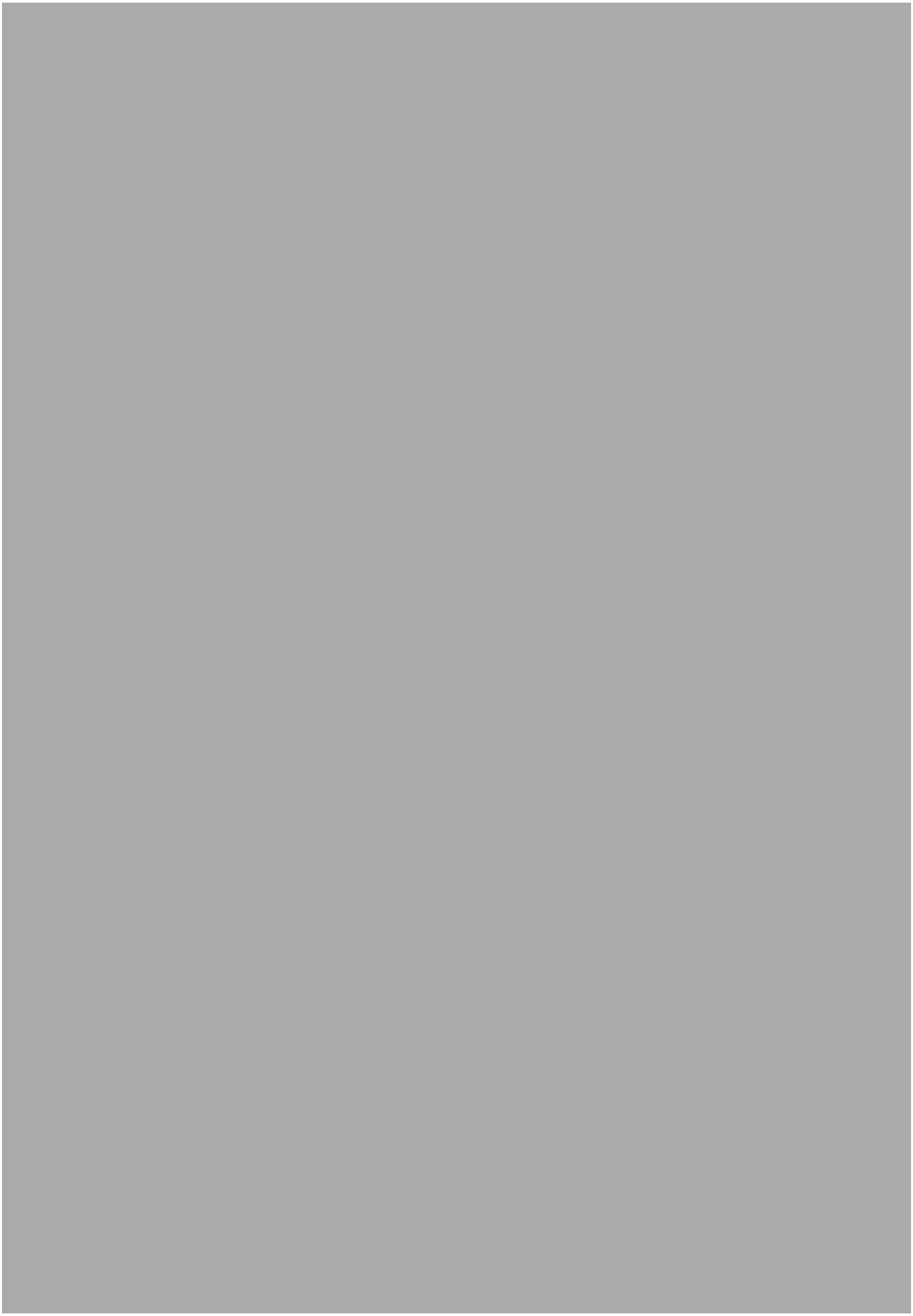
Appendix G: Characteristics of 40 UK TT firms Interviewed

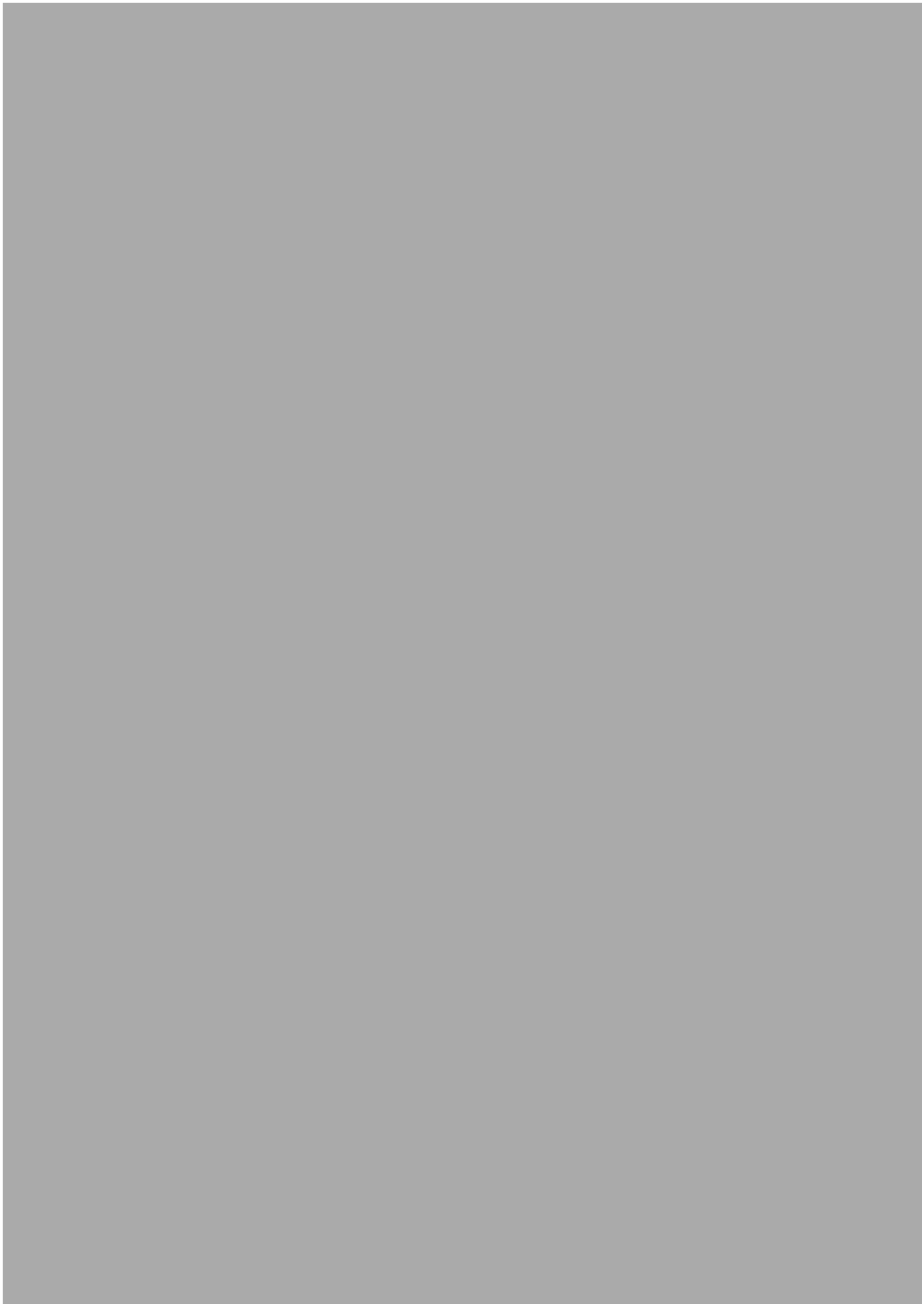
Appendix H: NVivo Analytical Coding Structure

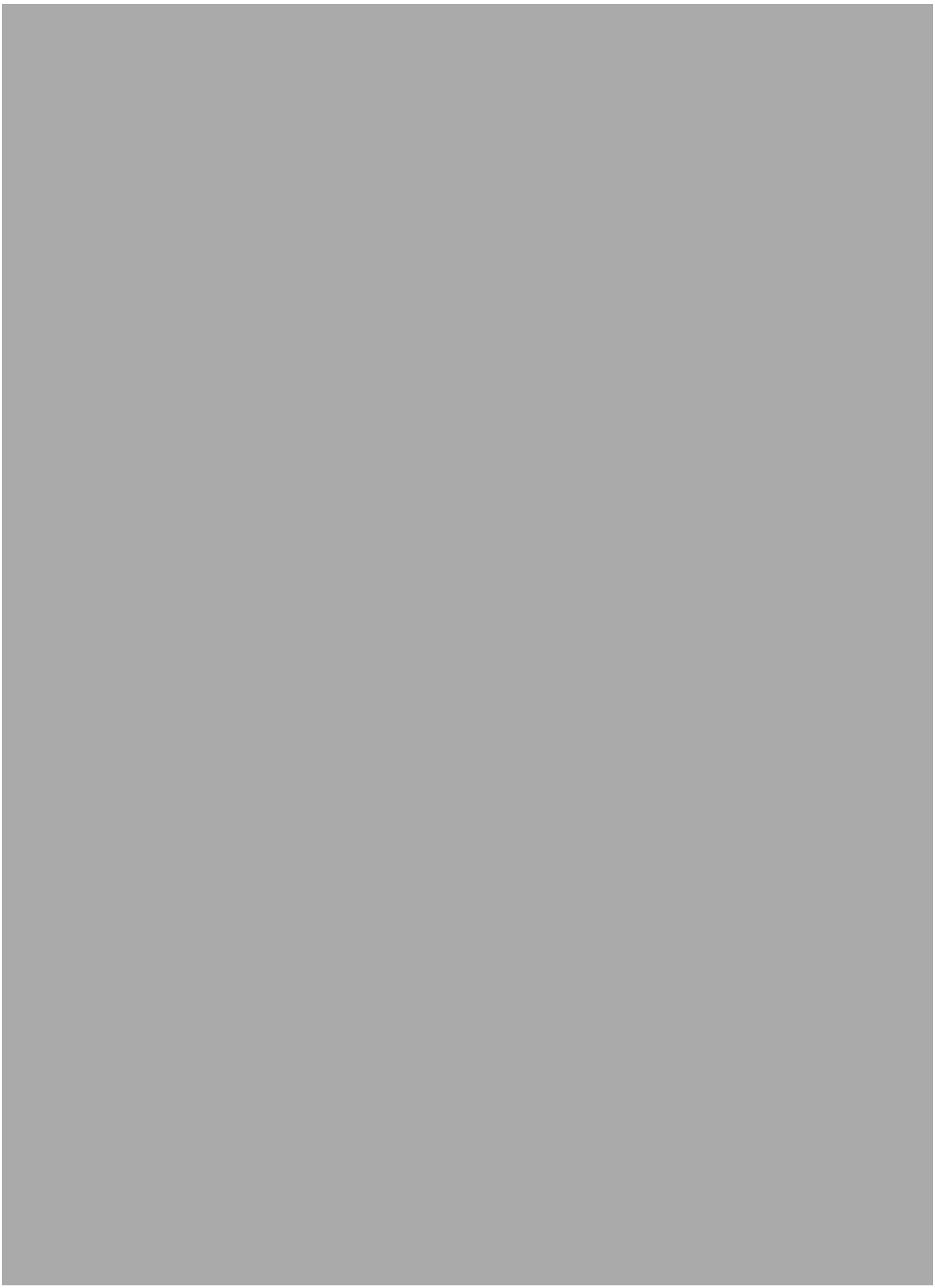
Industry (SIC 2007)	Sub-Industry	Micro-Industry	Description of Industry
13			**Manufacture of Textiles**
	131		Preparation and Spinning of Textile Fibres
	132		Weaving of Textiles
	133		Finishing of Textiles
	139		Manufacture of other Textiles
		1391	Manufacture of Knitted and Crocheted Fabrics
		1392	Manufacture of made-up Textile Articles, Except Apparel
		1393	Manufacture of Carpets and Rugs
		1394	Manufacture of Cordage, Rope, Twine, and Netting
		1395	Manufacture of Nonwovens and Articles made from Nonwovens, Except Apparel
		1396	Manufacture of Technical and Industrial Textiles
		1399	Manufacture of other Textiles
14			**Manufacture of Wearing Apparel**
	141		Manufacture of Wearing Apparel, Except Fur Apparel
		1411	Manufacture of Leather Clothes
		1412	Manufacture of Workwear
		1413	Manufacture of other Outerwear
		1414	Manufacture of Underwear
		1419	Manufacture of other Wearing Apparel and Accessories
	142		Manufacture of Articles of Fur
	143		Manufacture of Knitted and Crocheted Apparel
		1431	Manufacture of Knitted and Crocheted Apparel
		1439	Manufacture of other Knitted and Crocheted Apparel

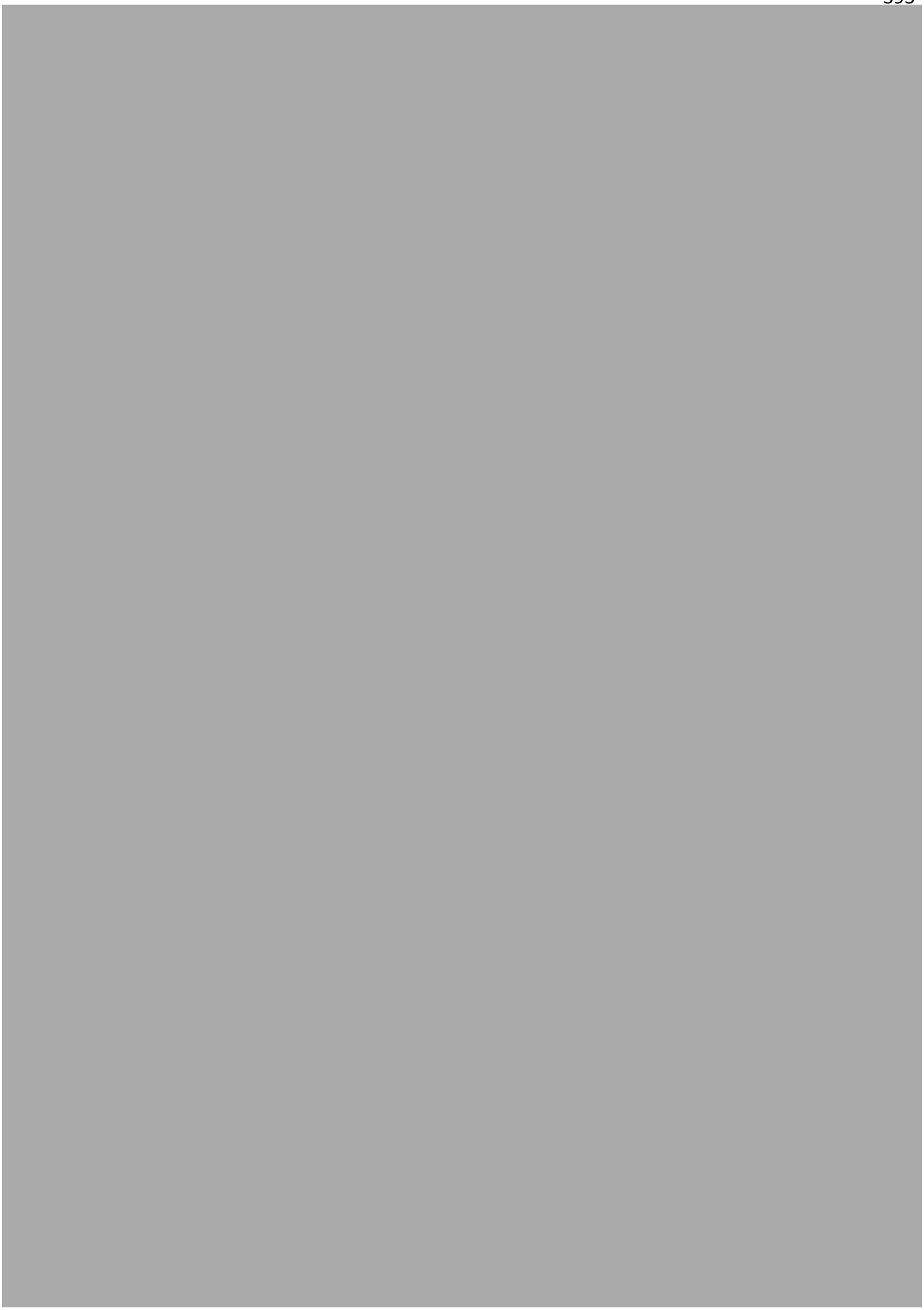
Source: FAME (2014)

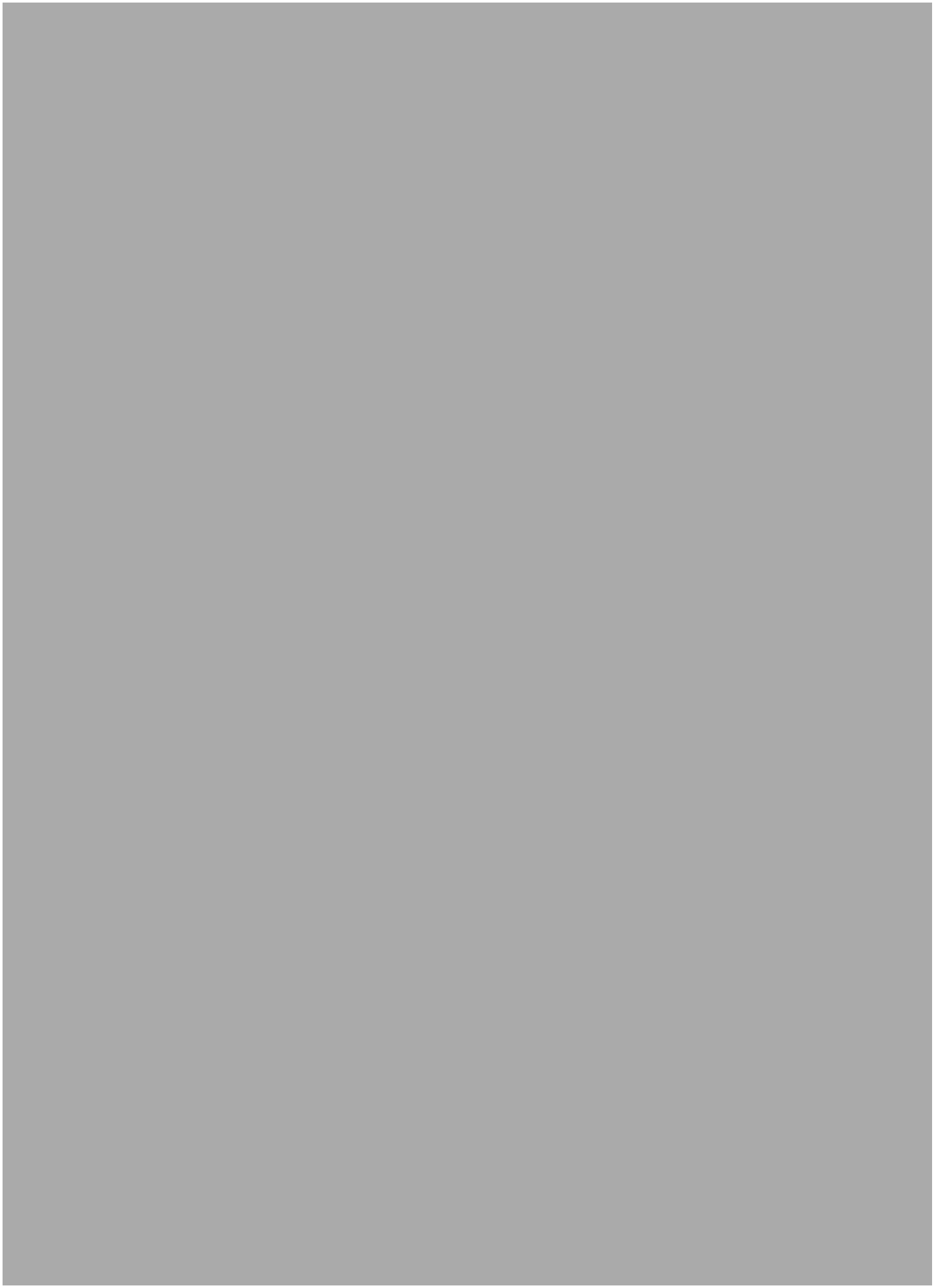


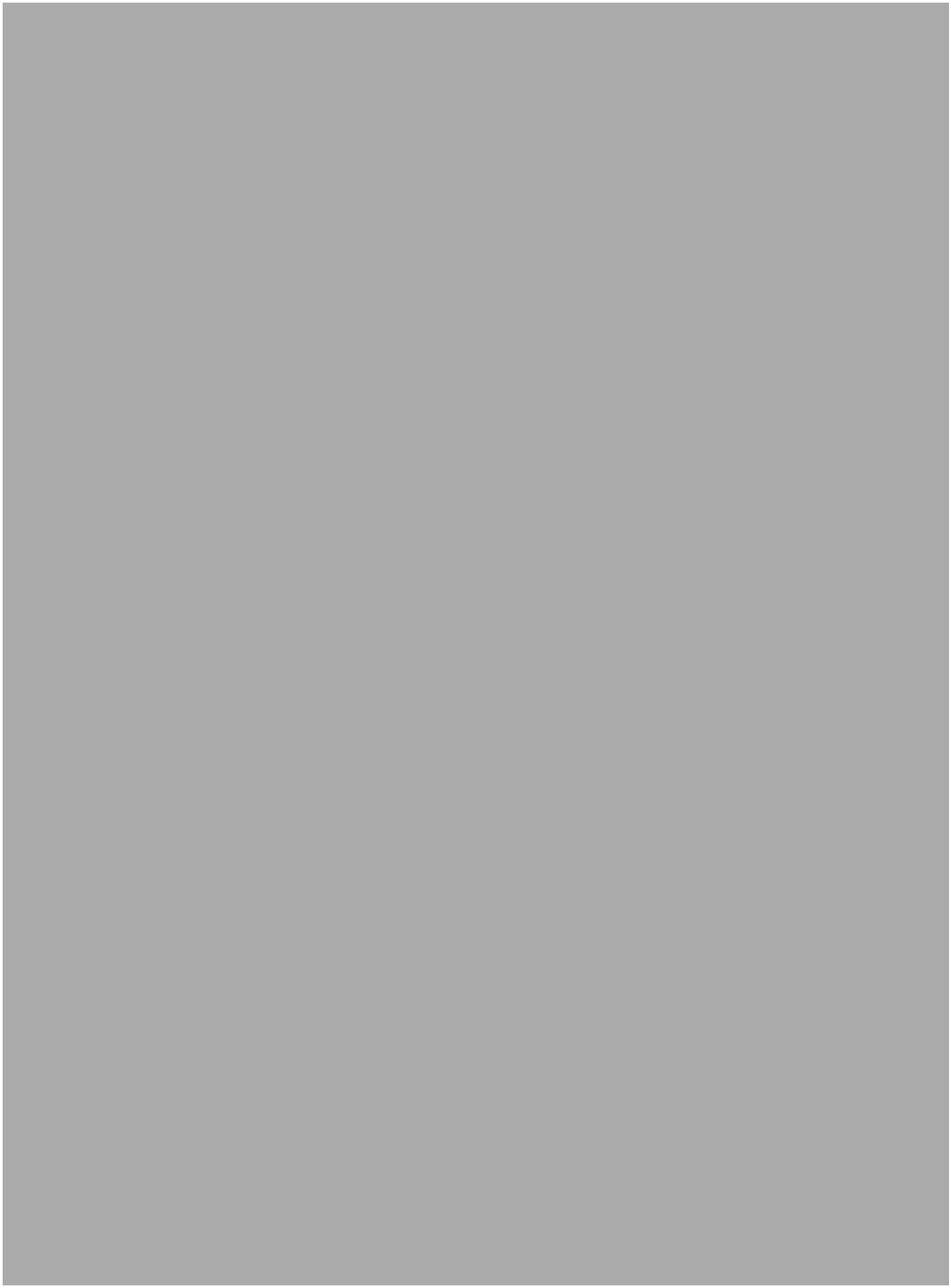


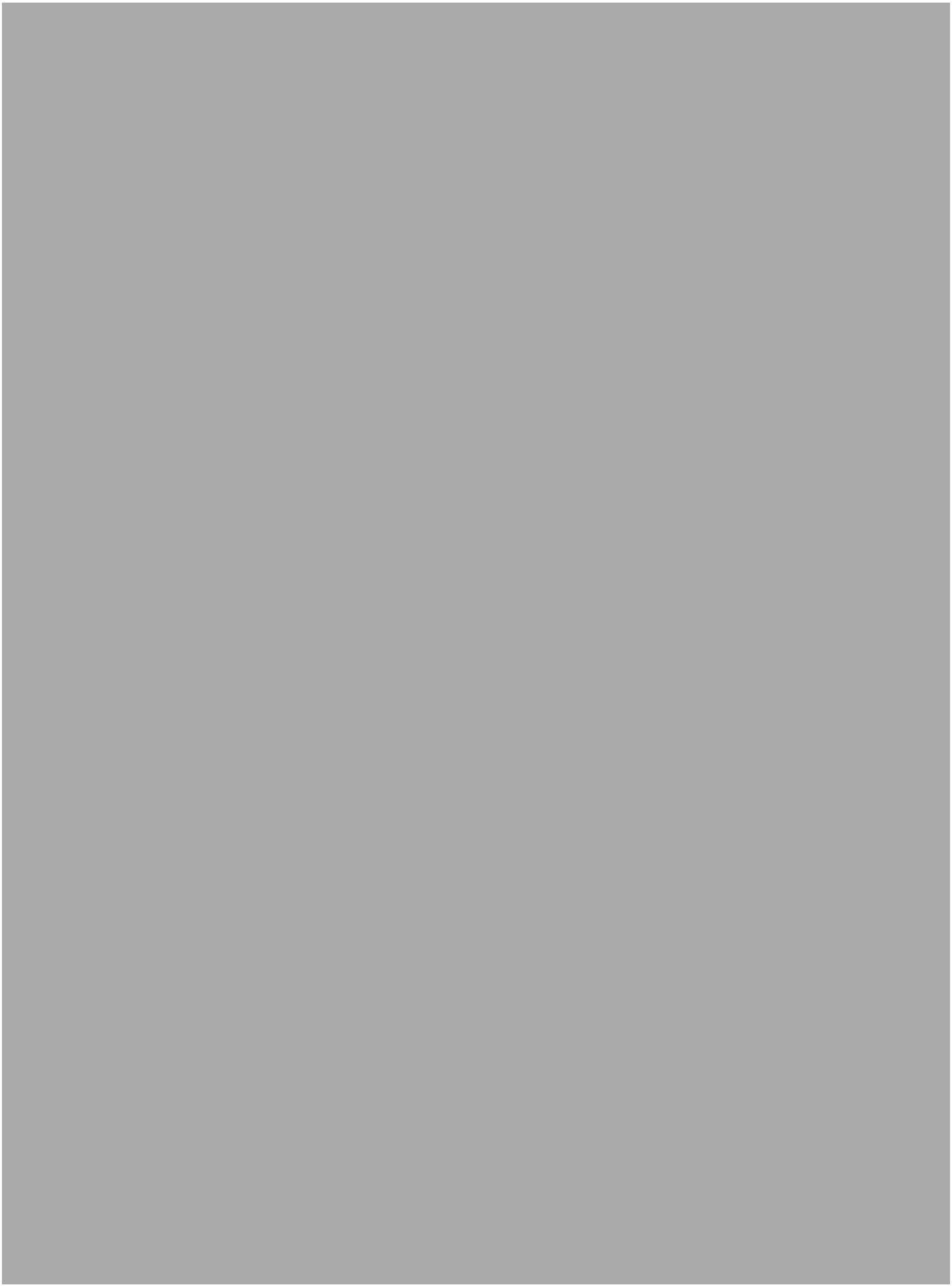


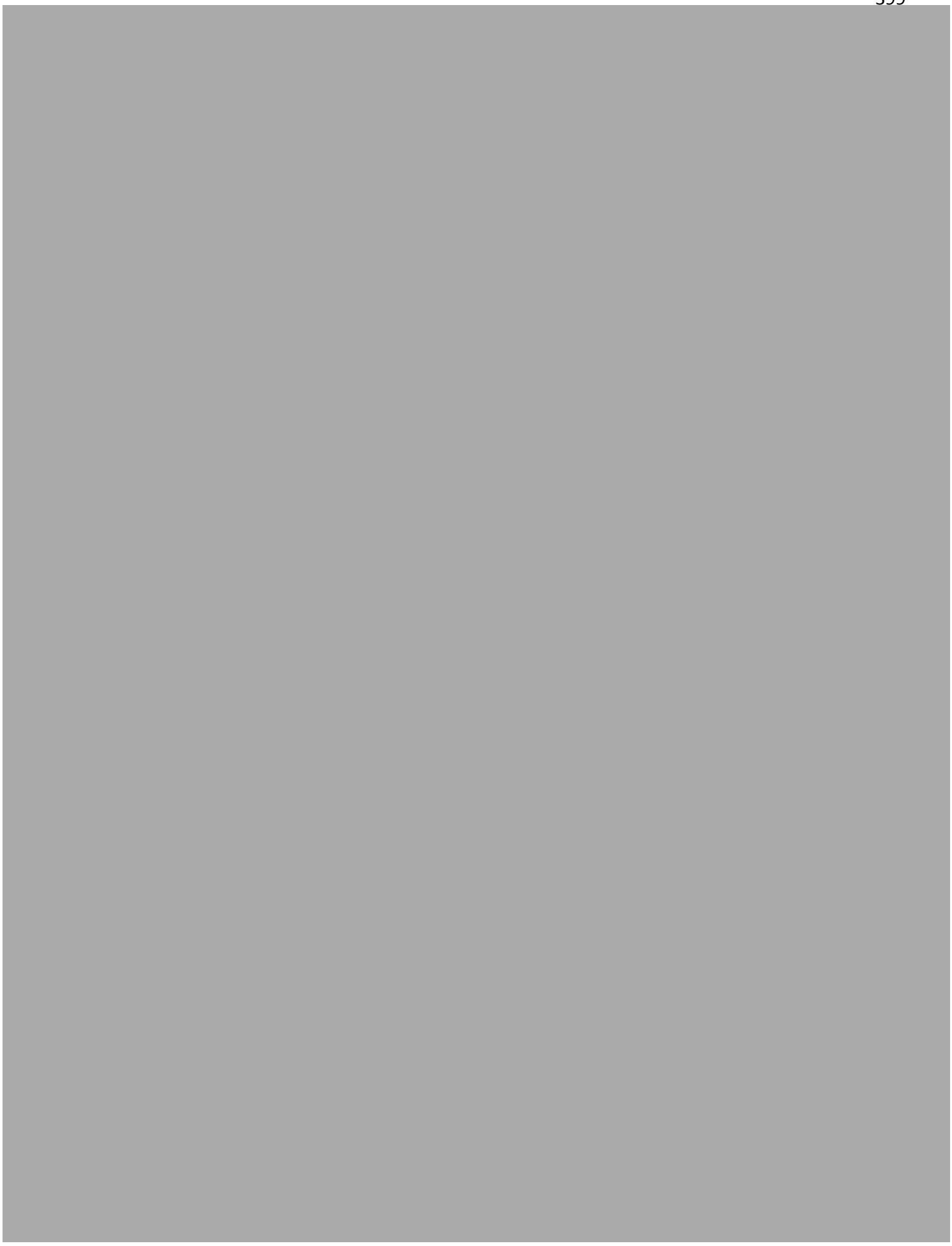


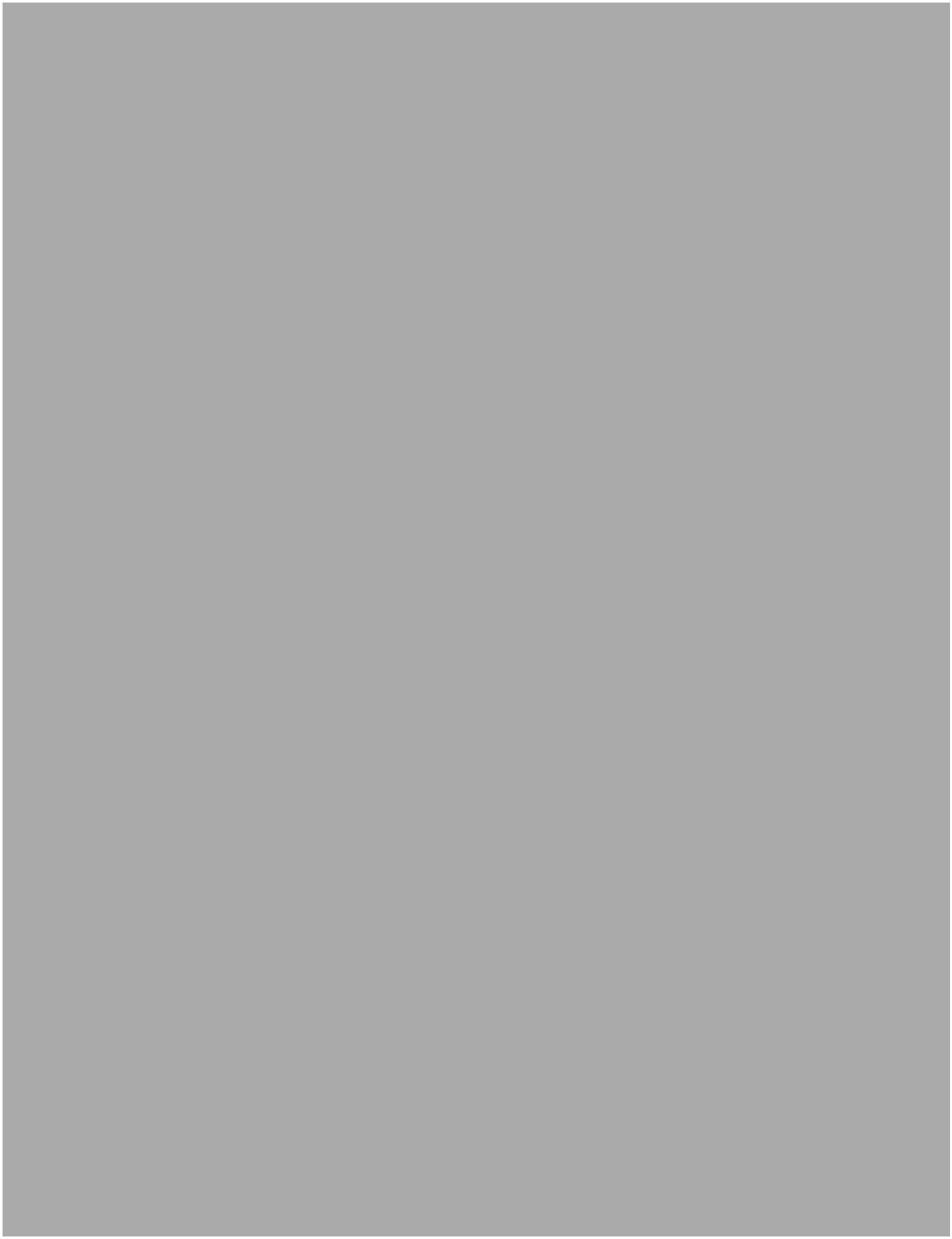


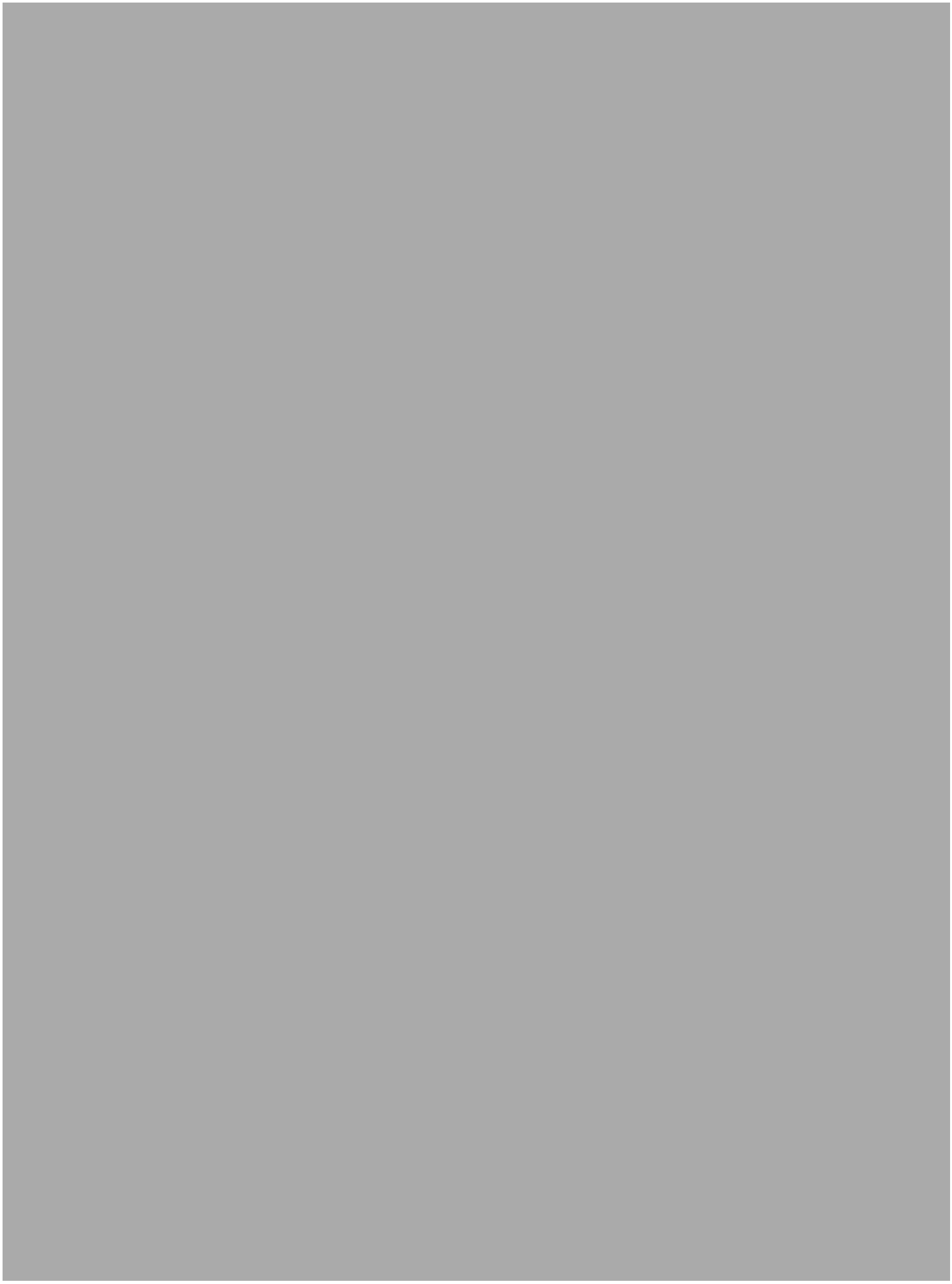


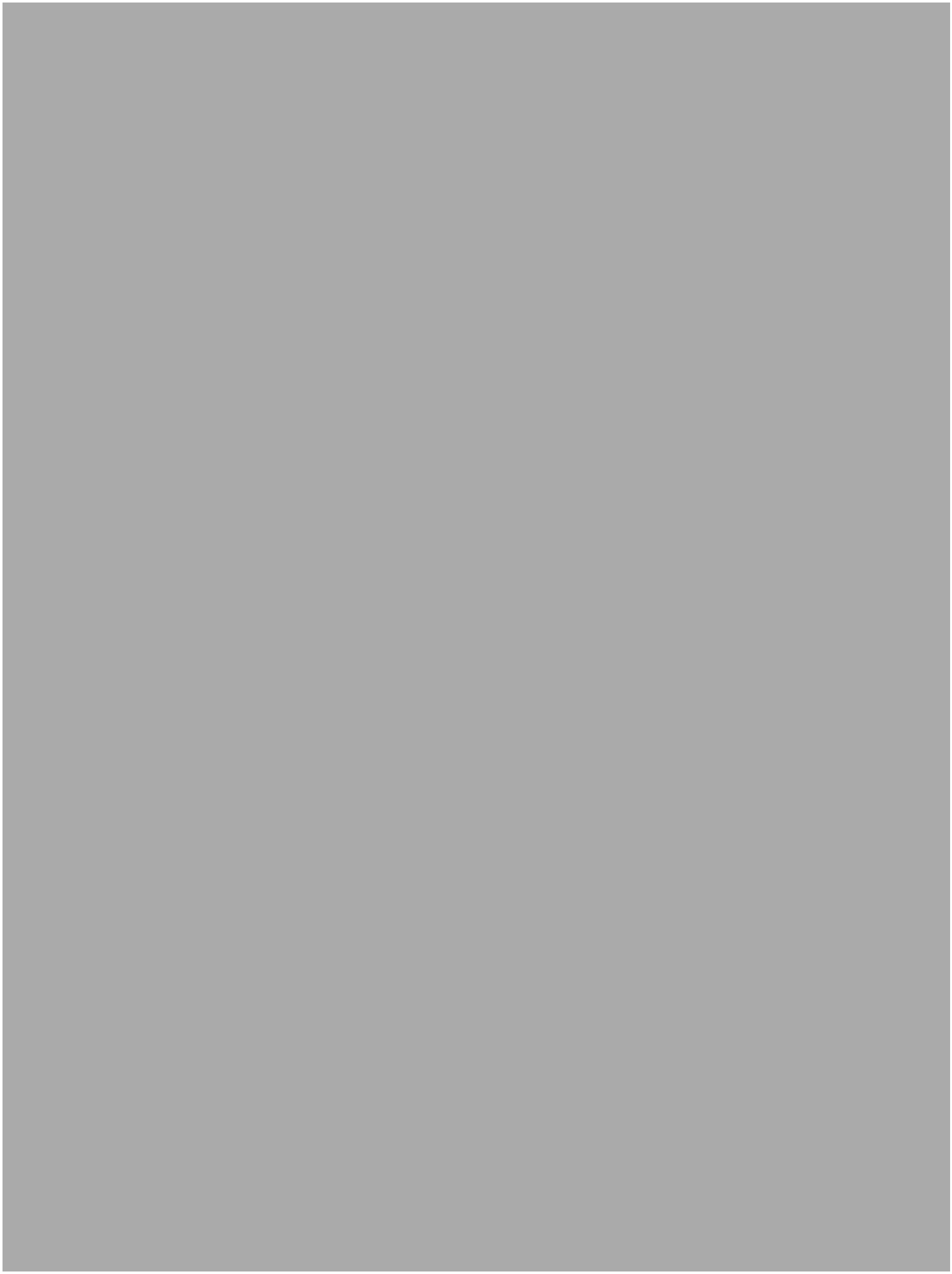


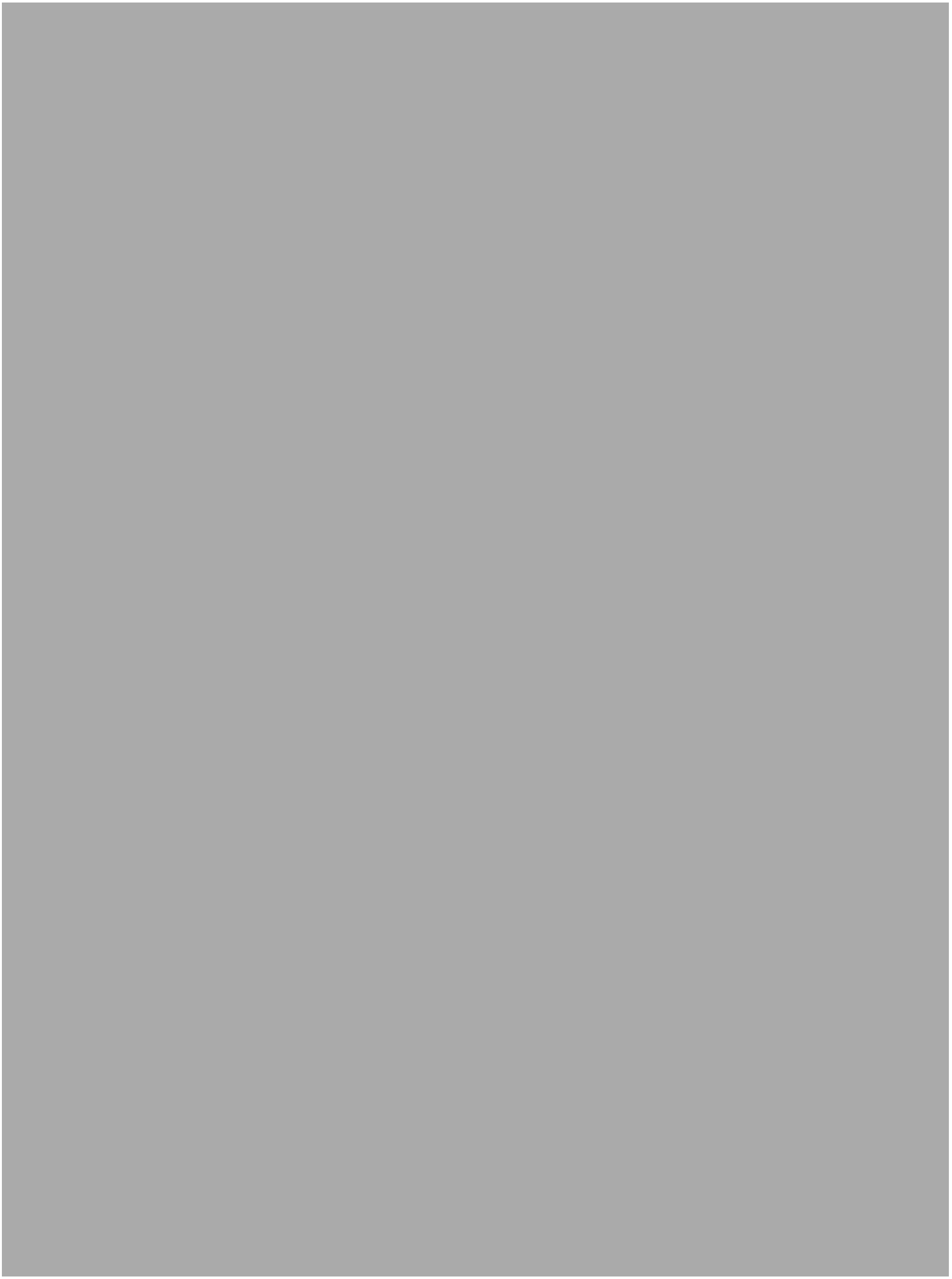


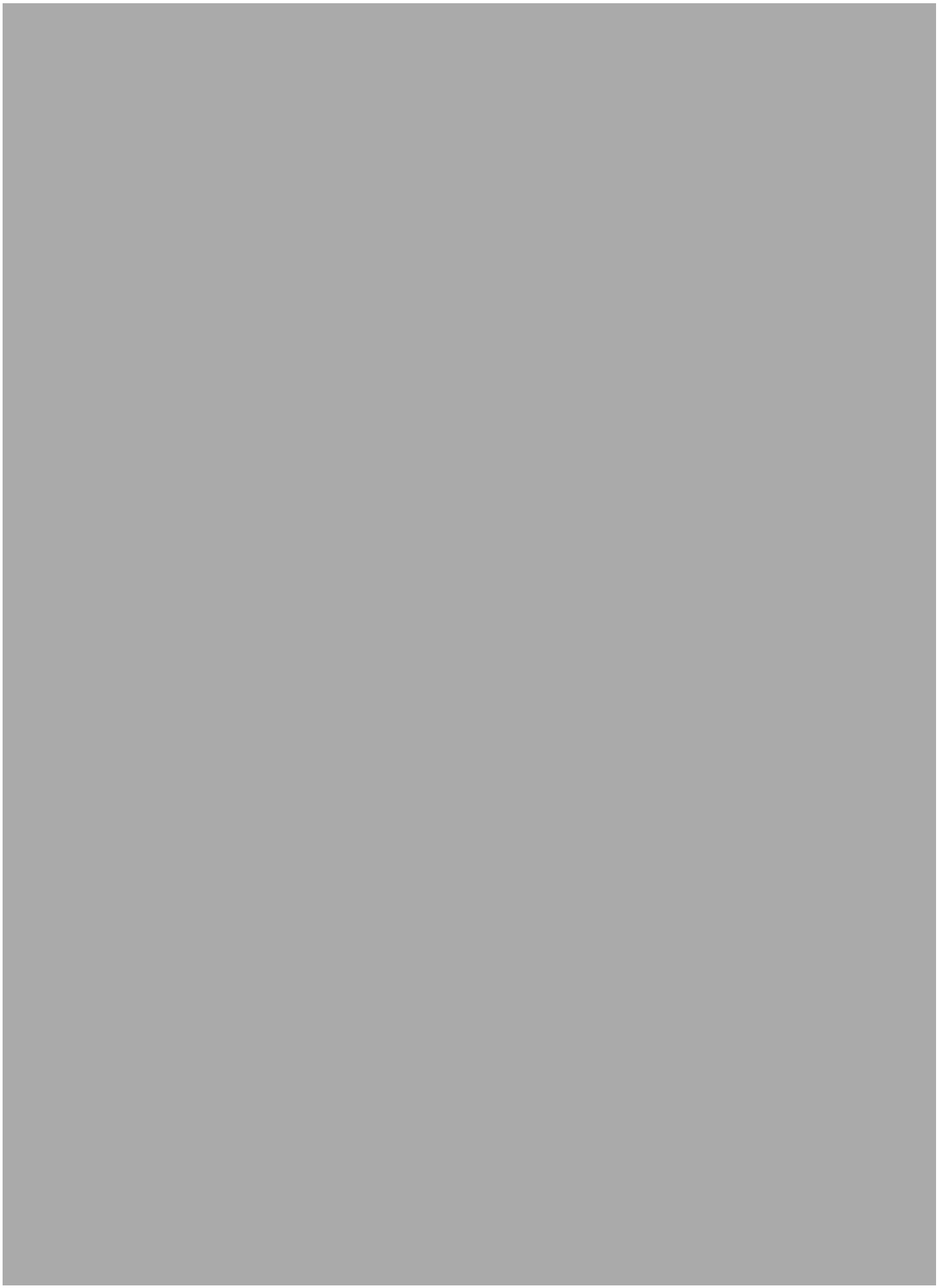


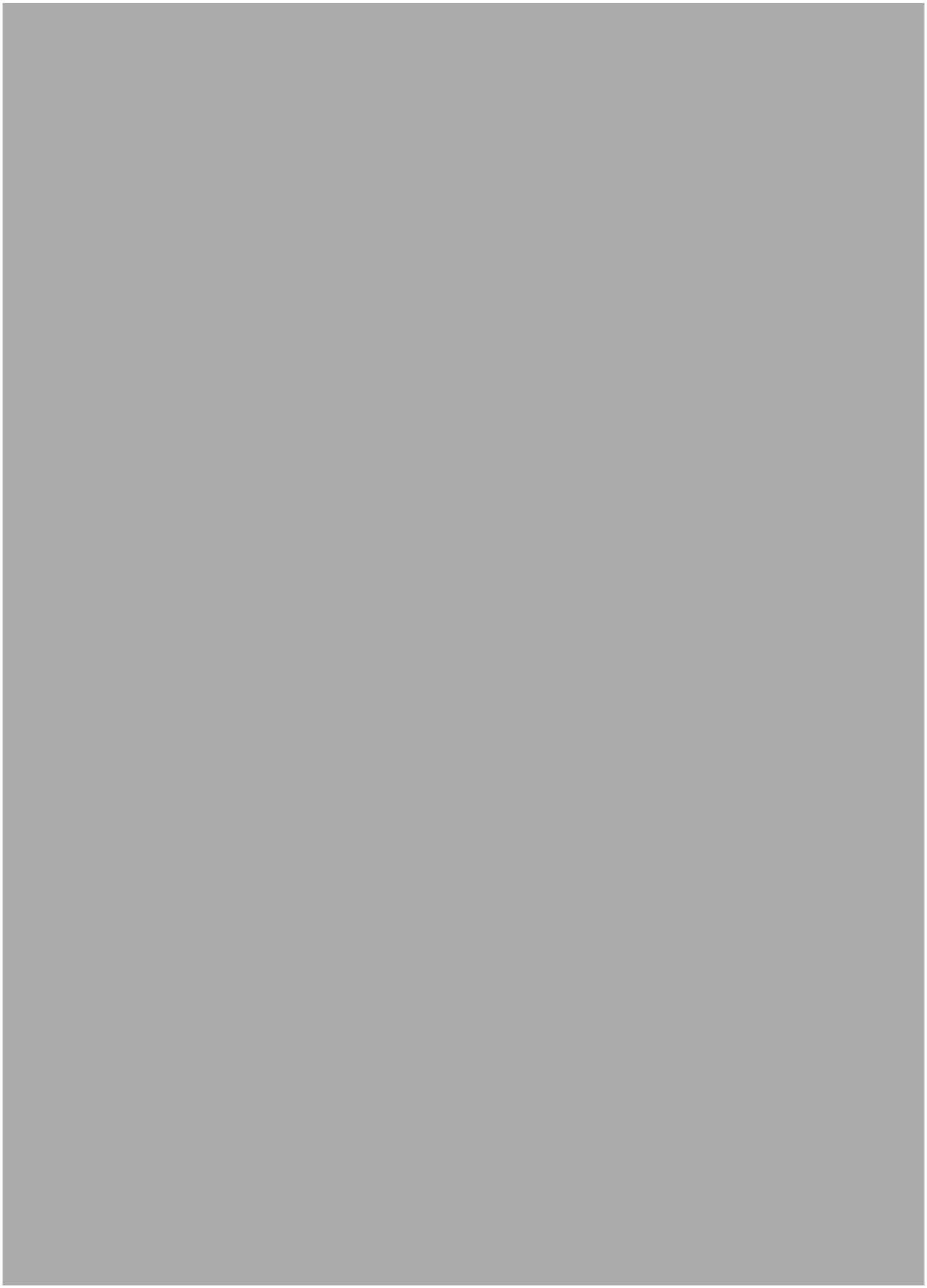


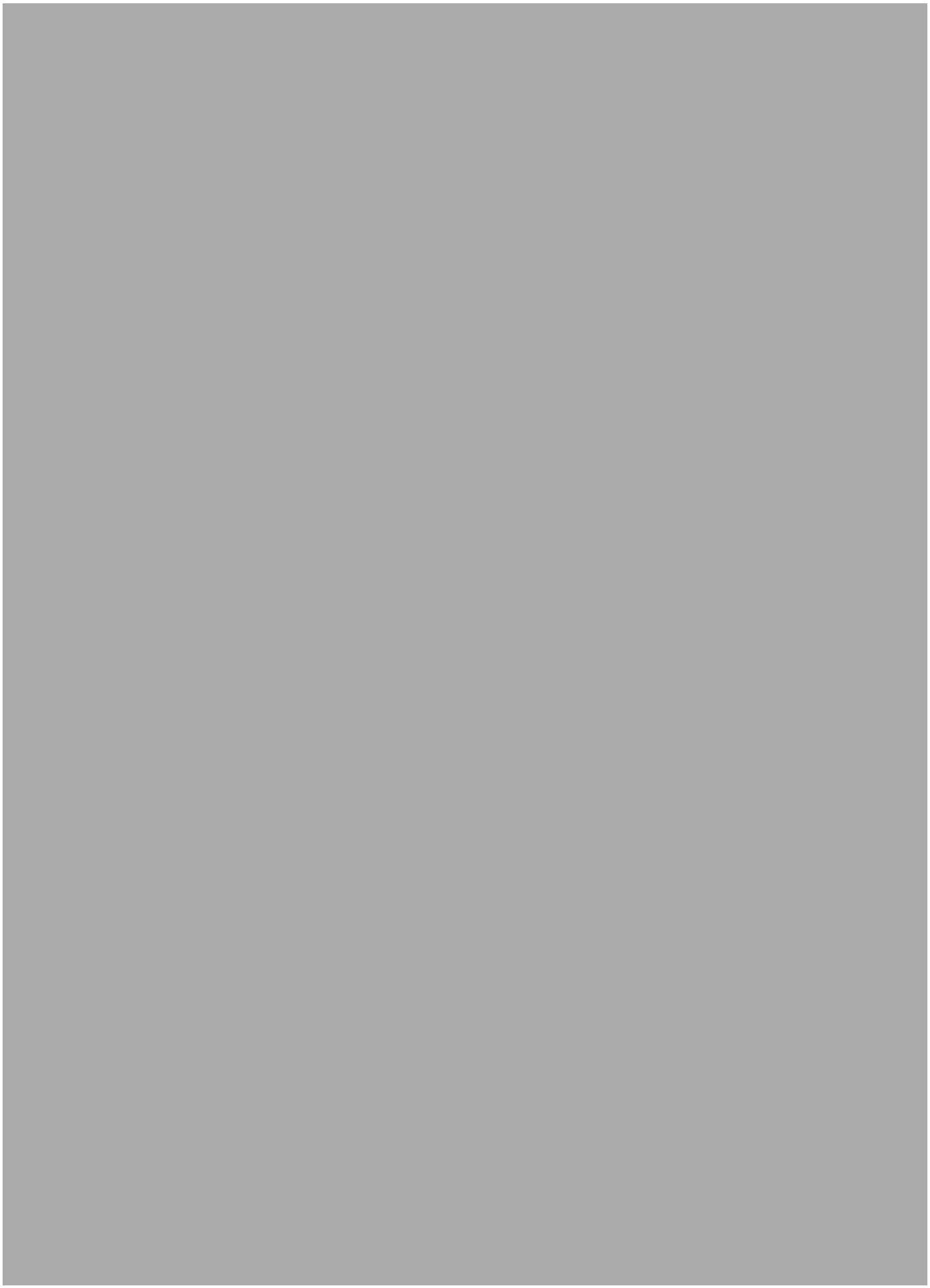


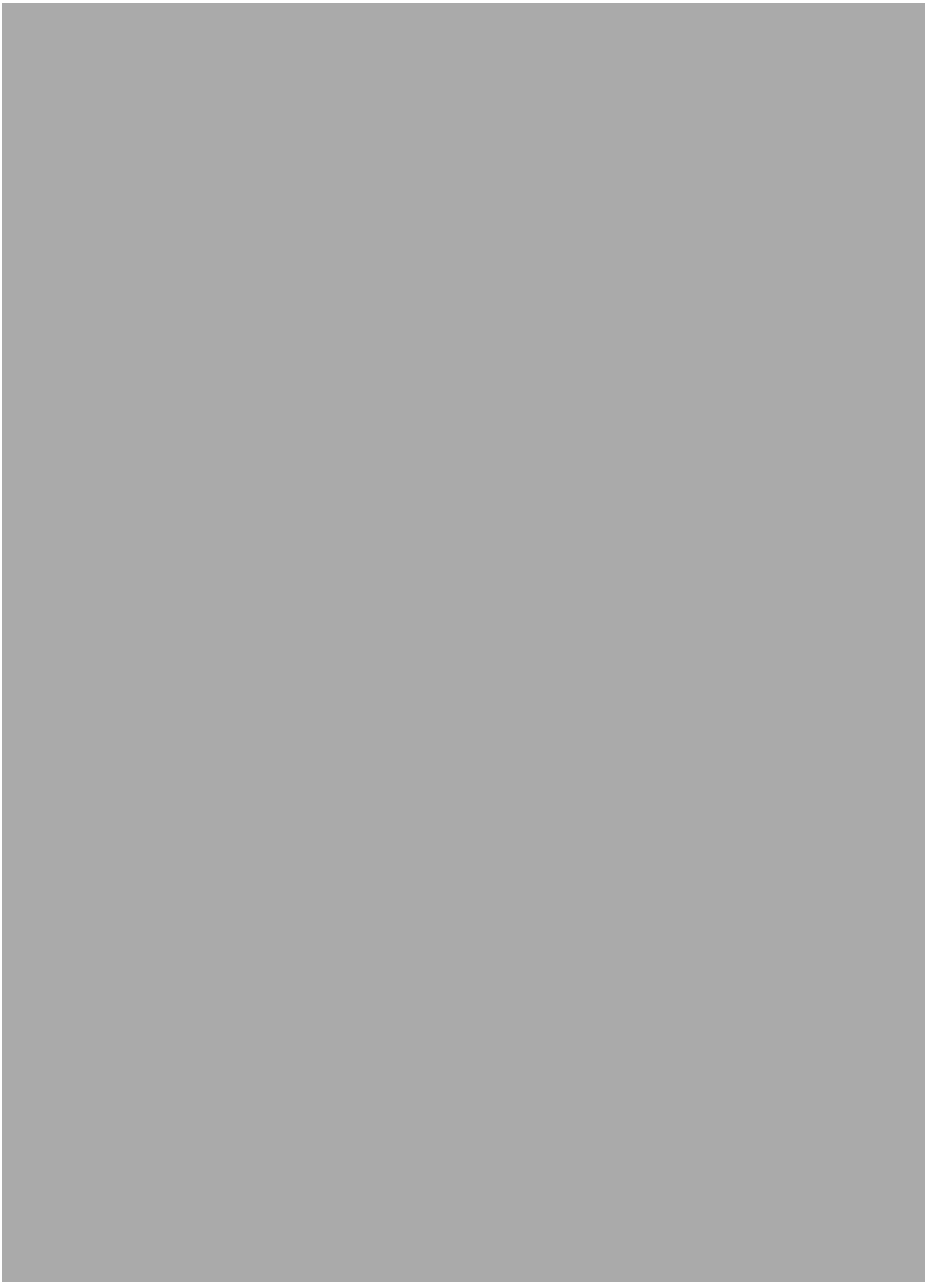


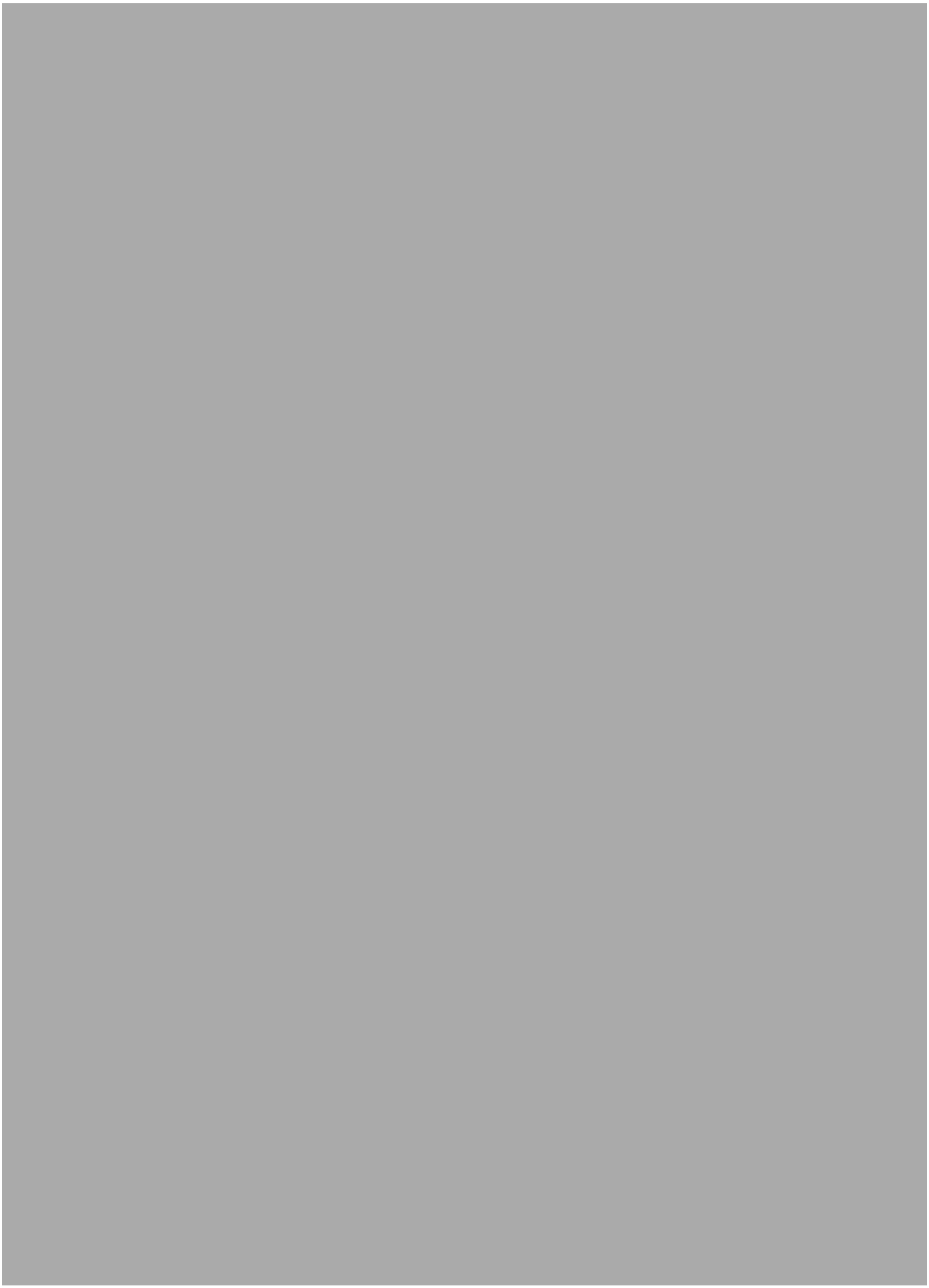


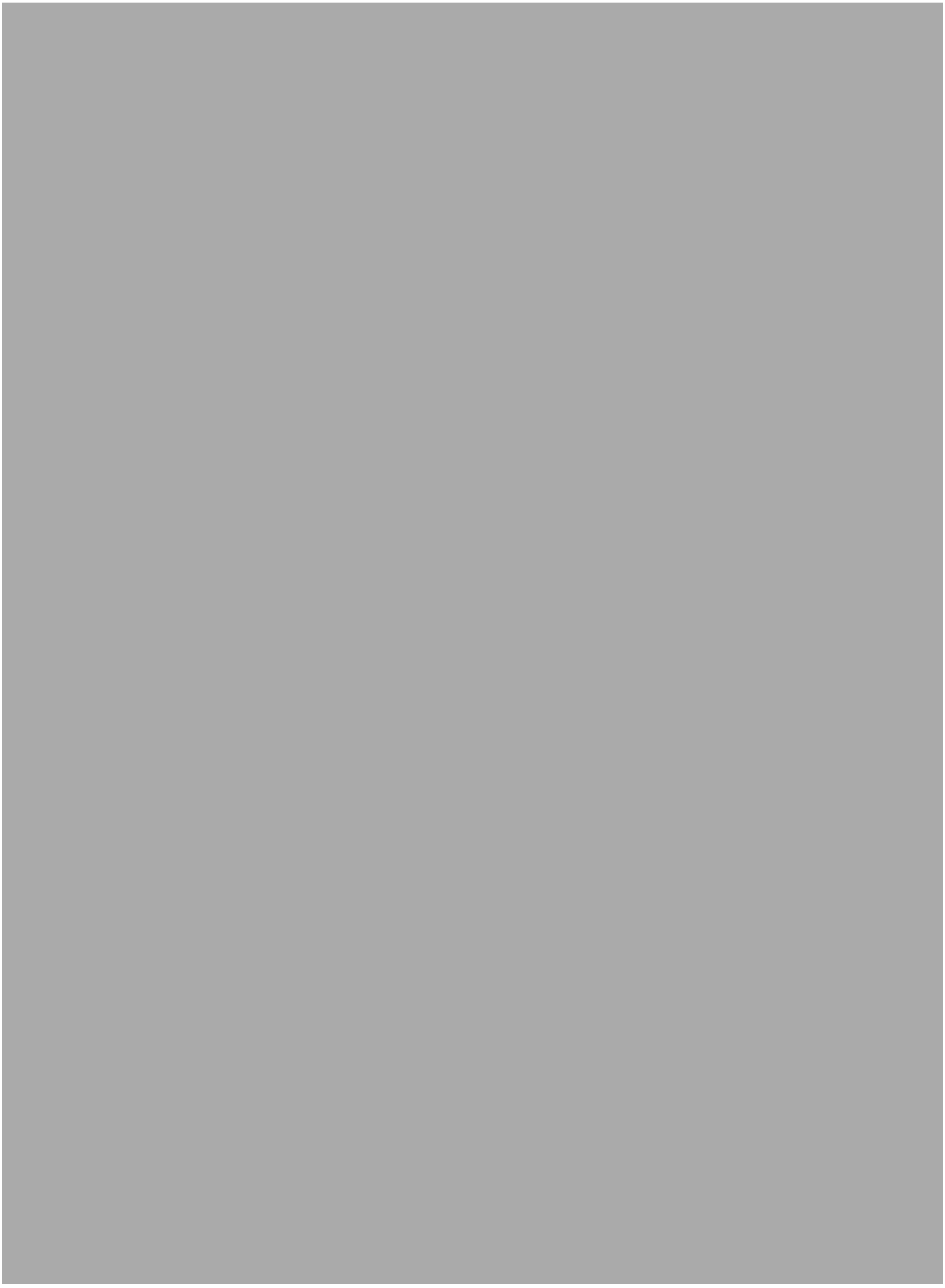


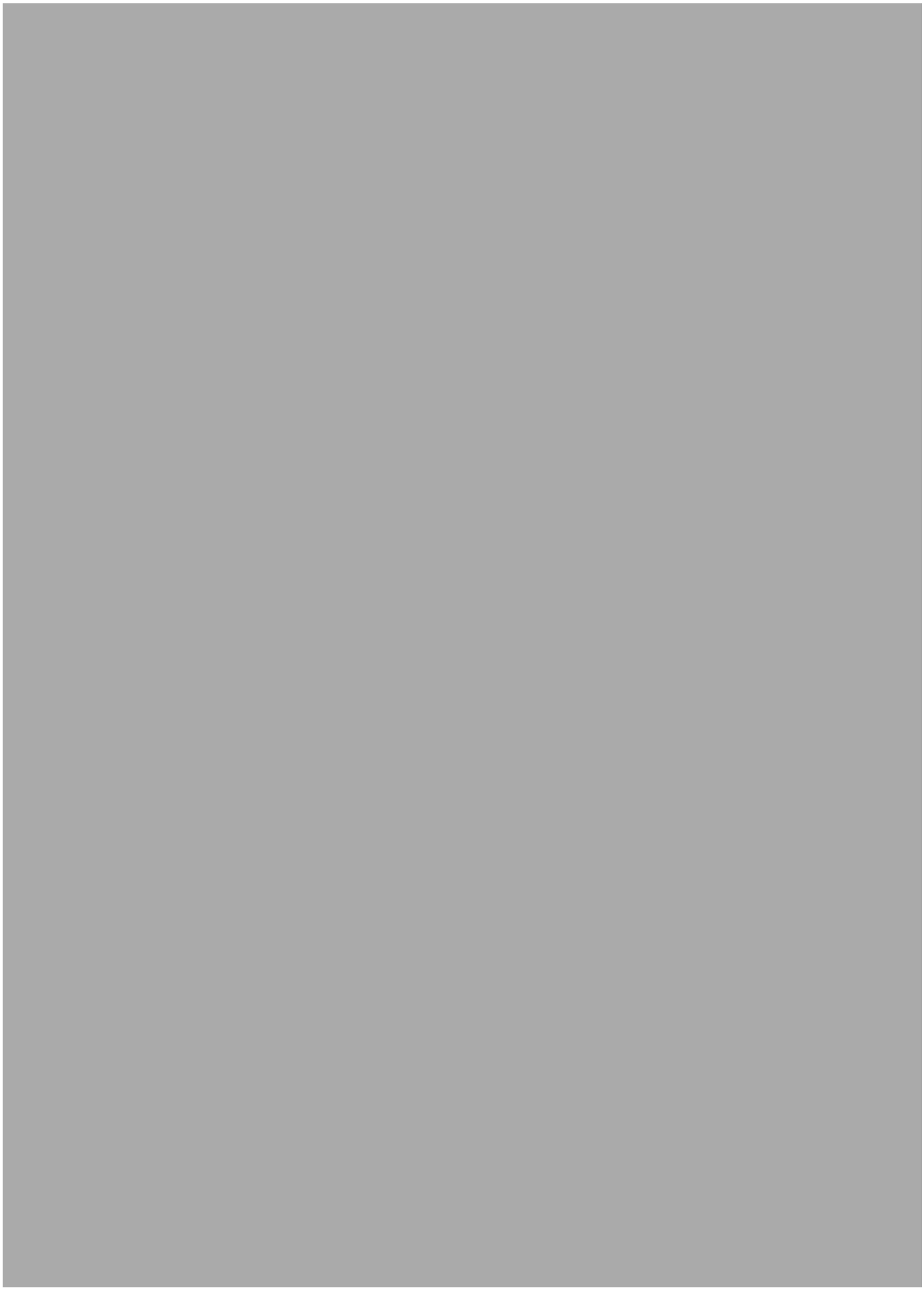


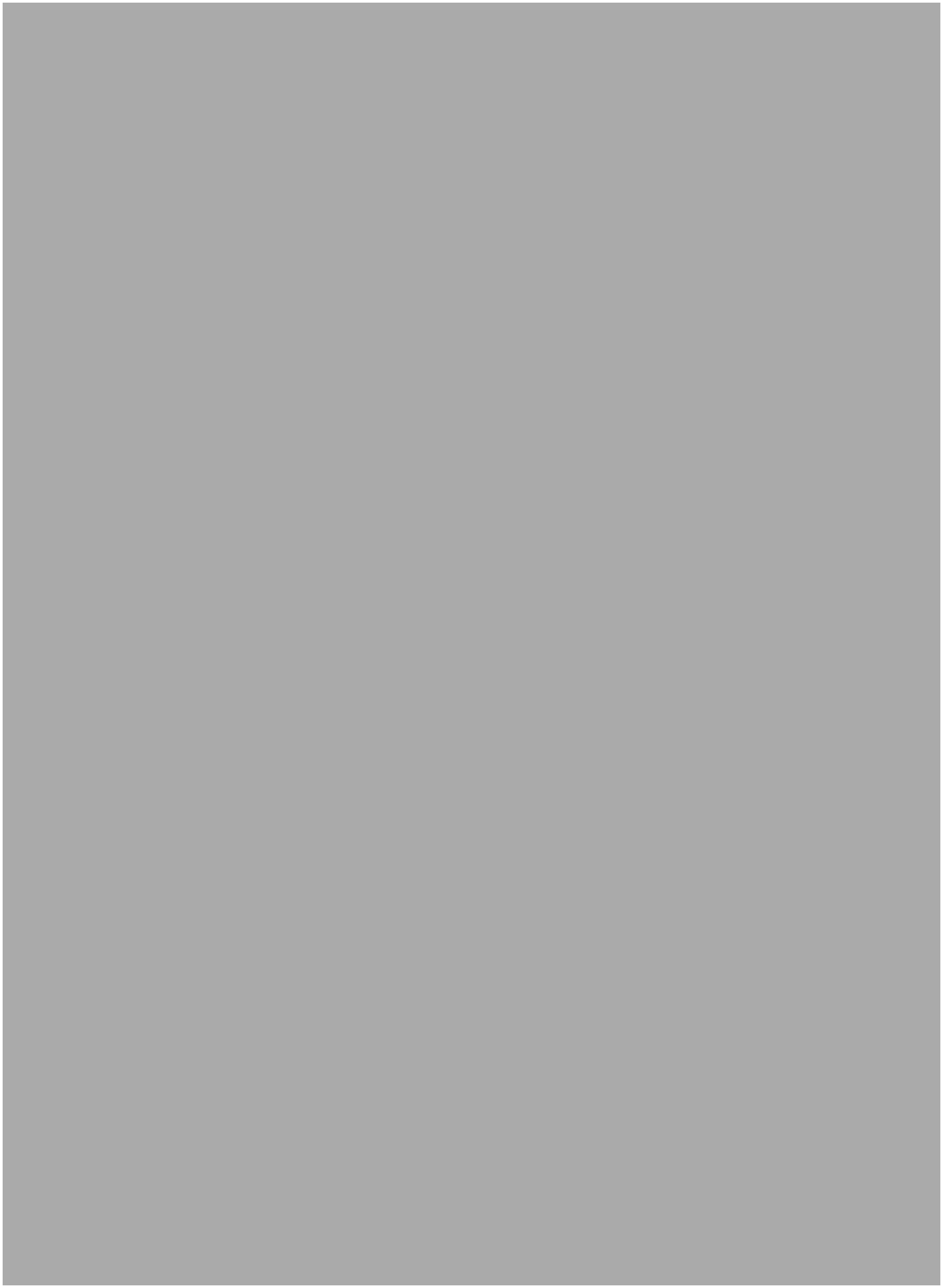


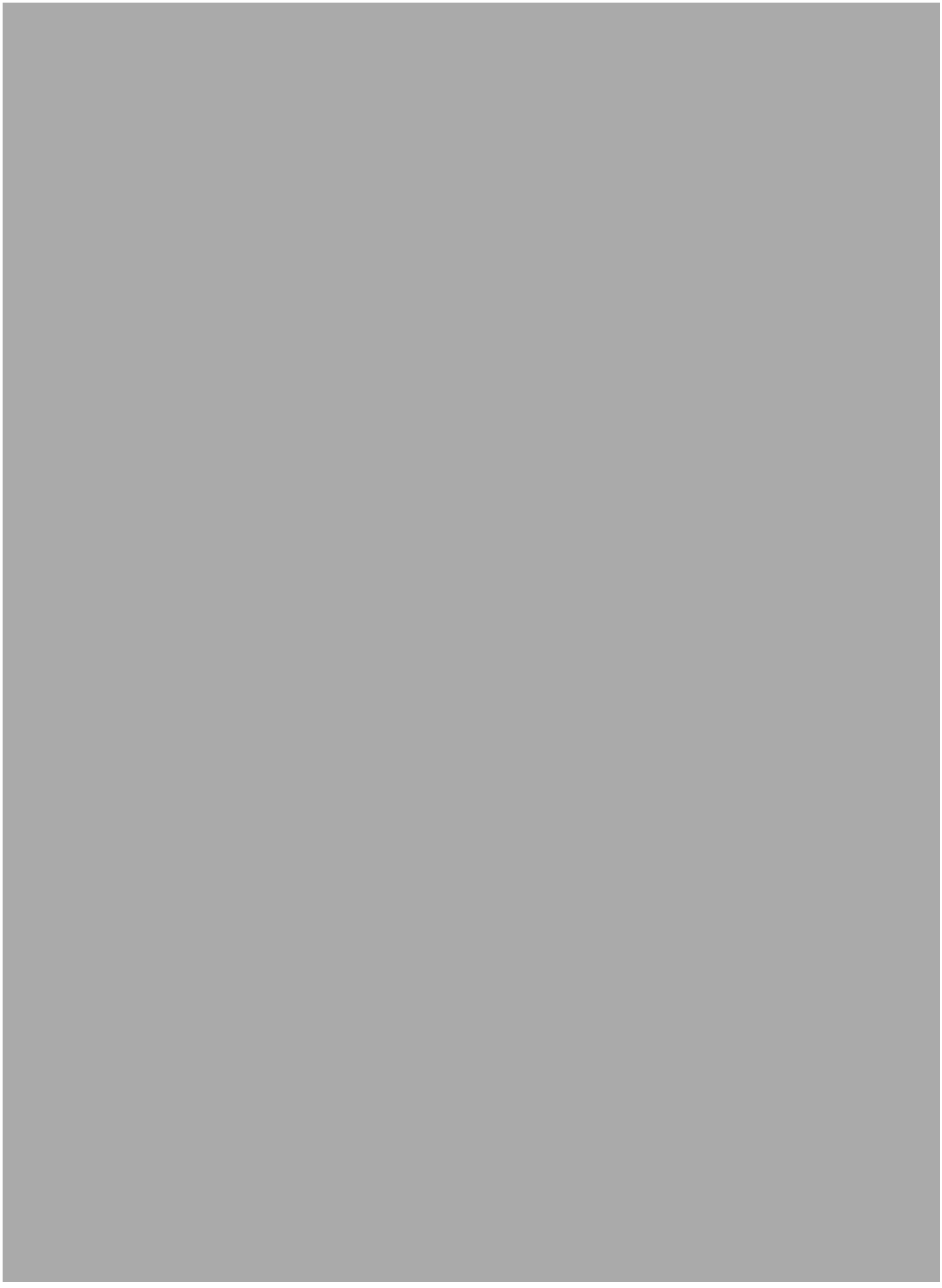


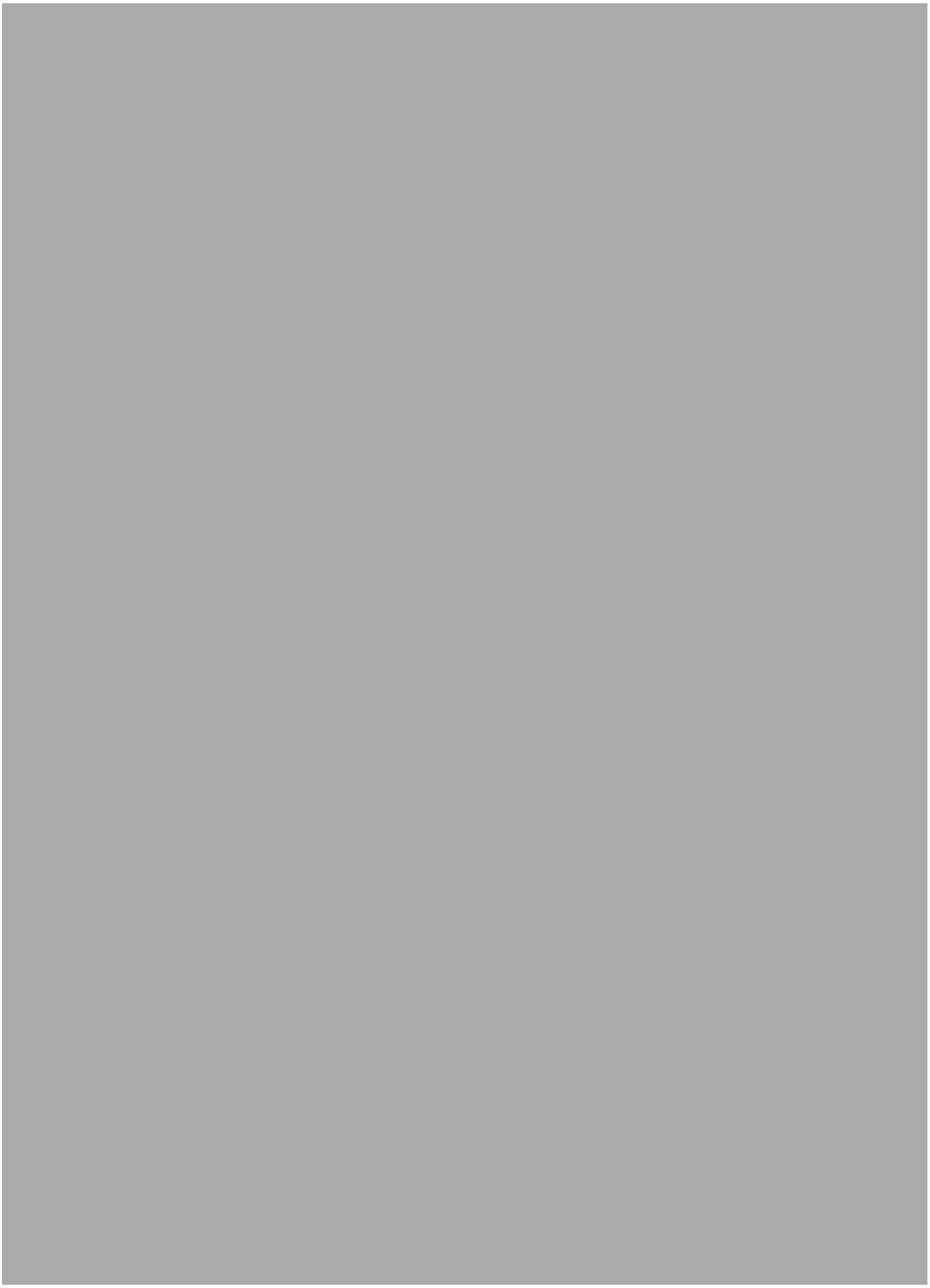


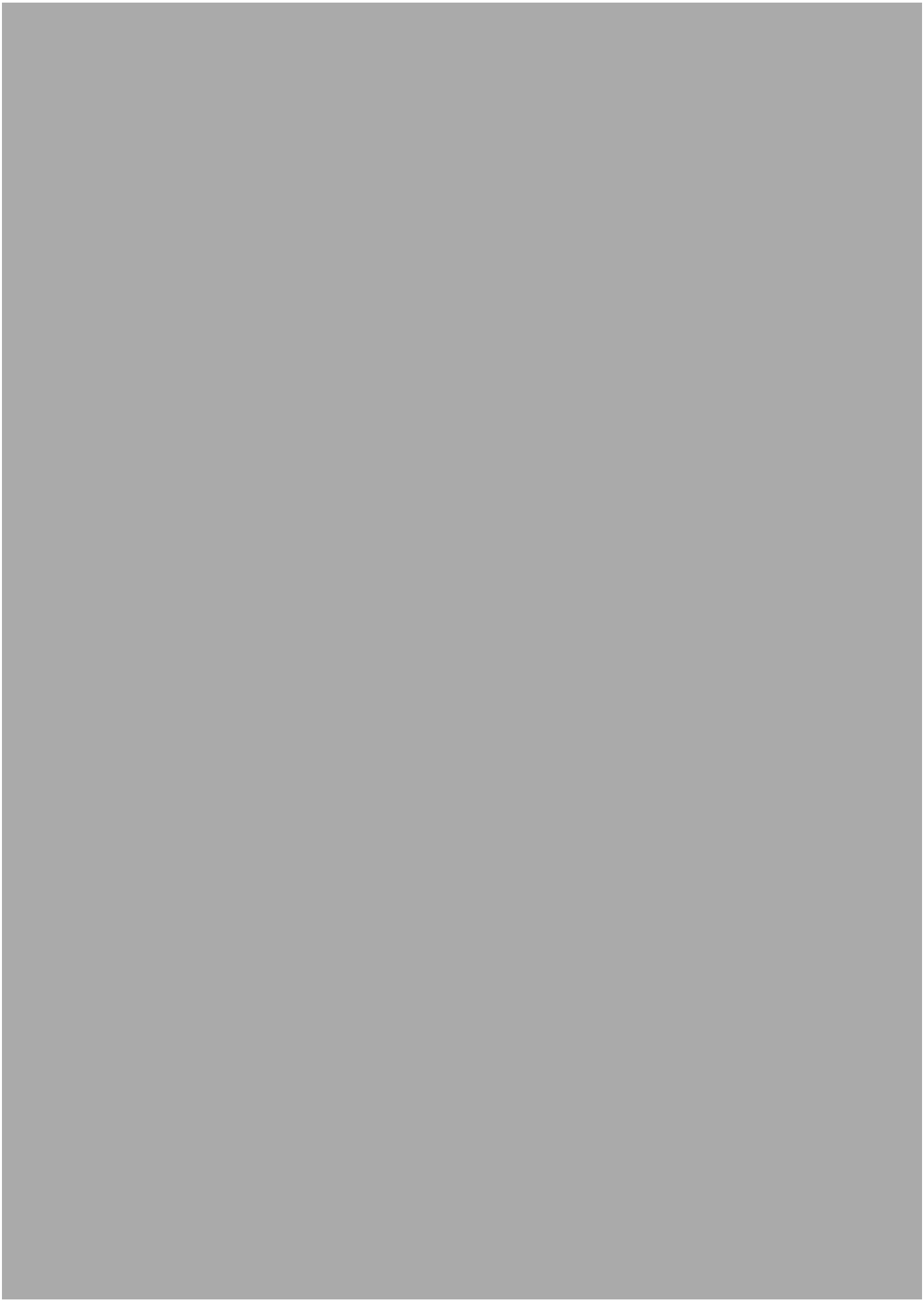




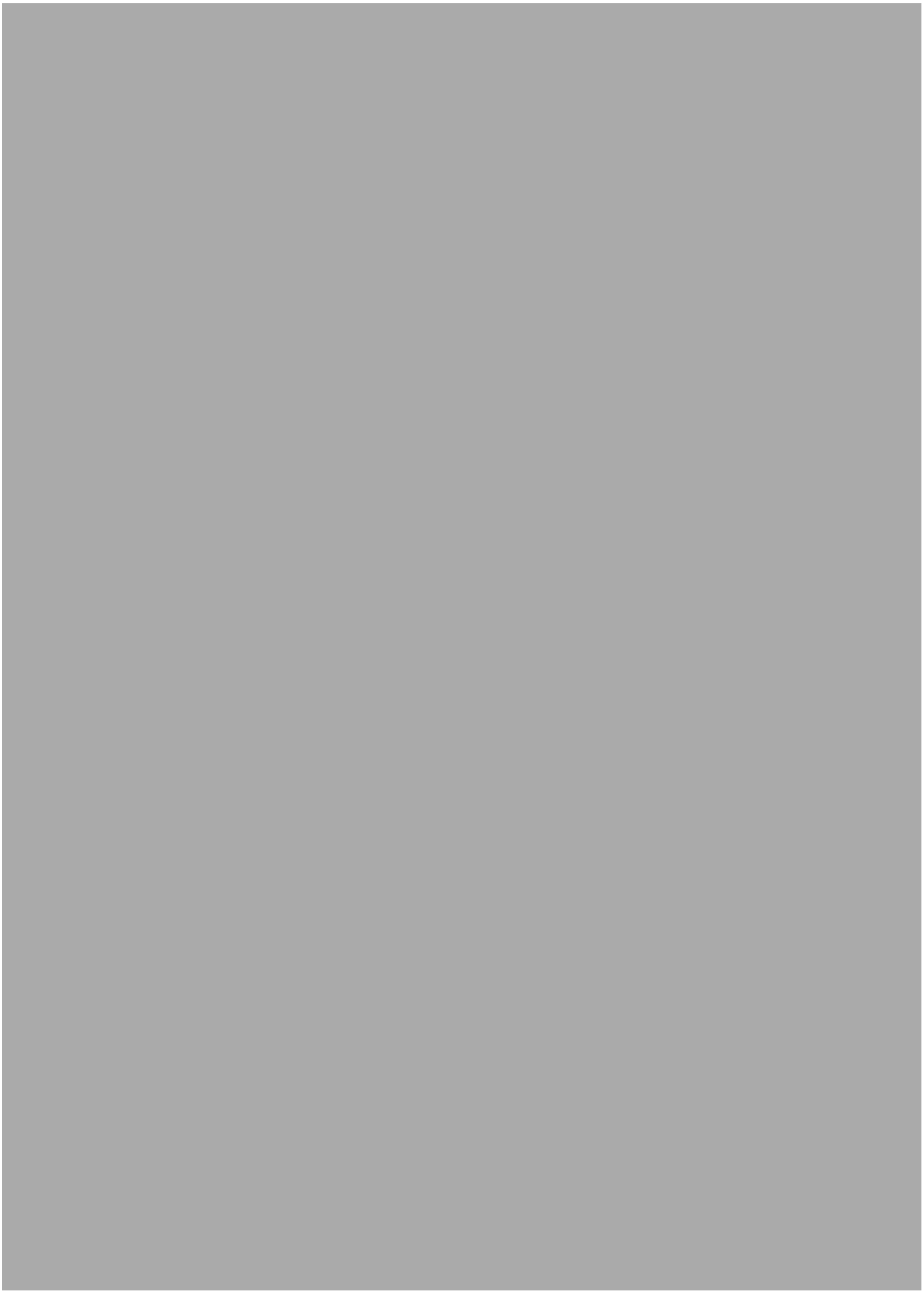


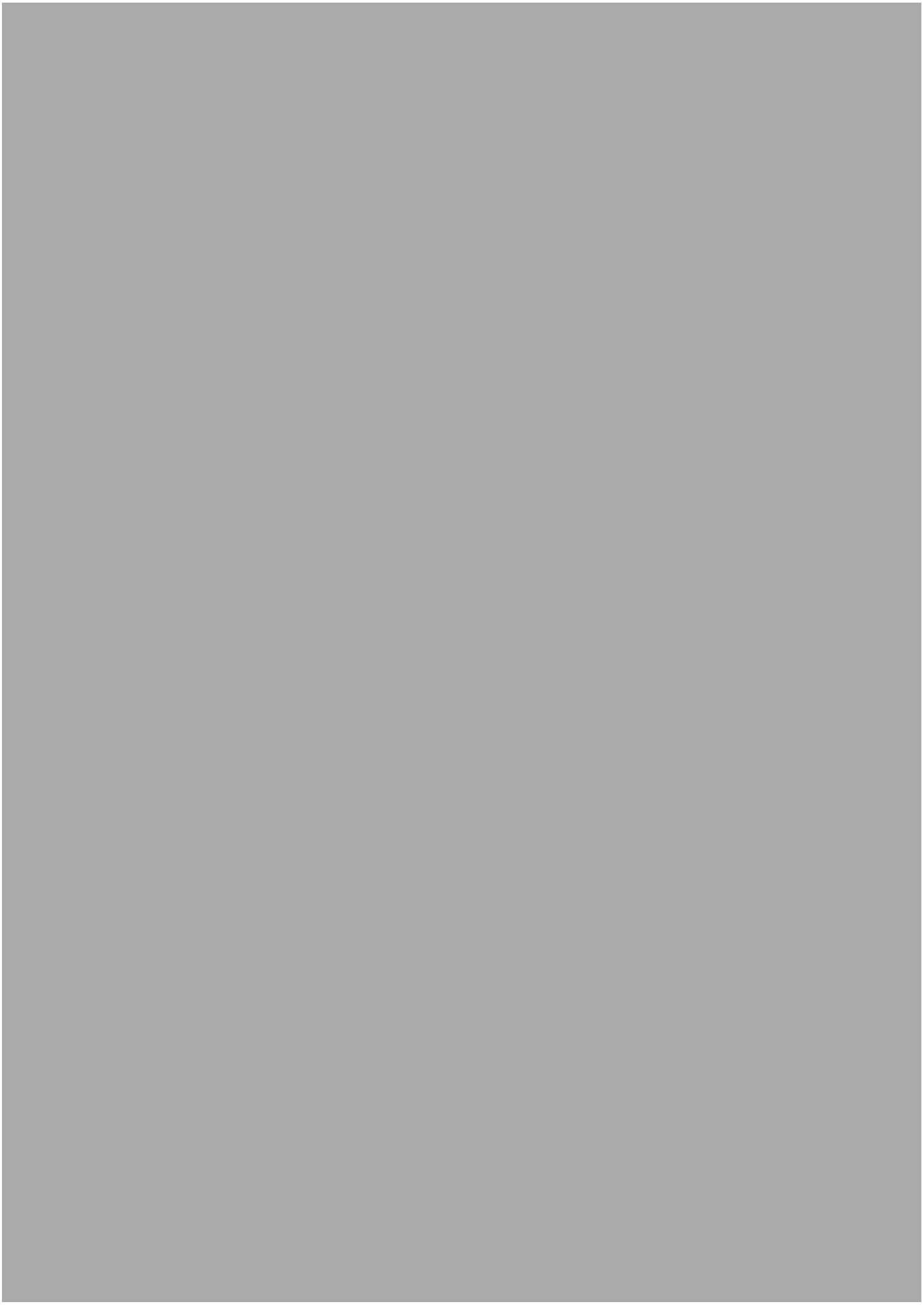


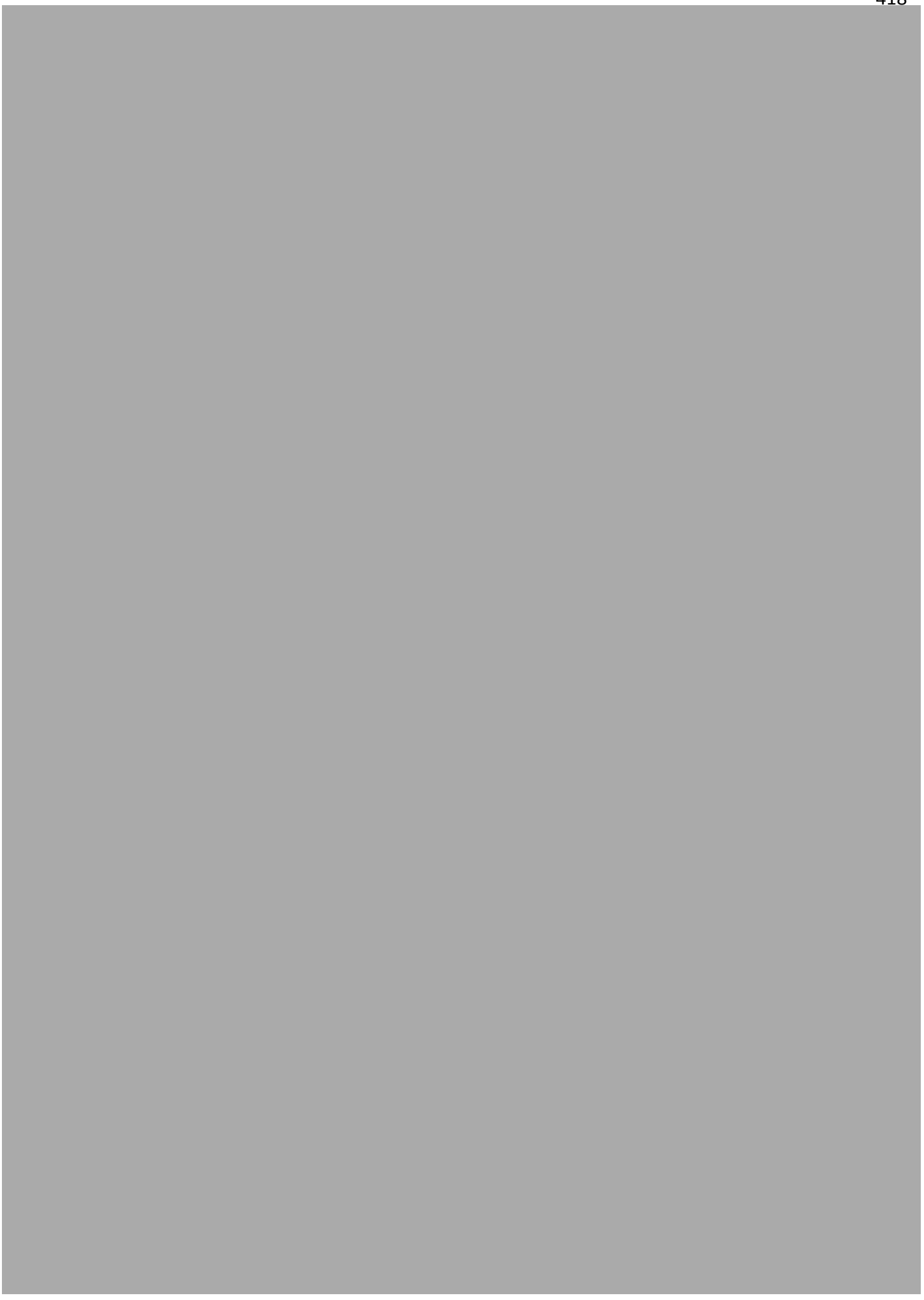


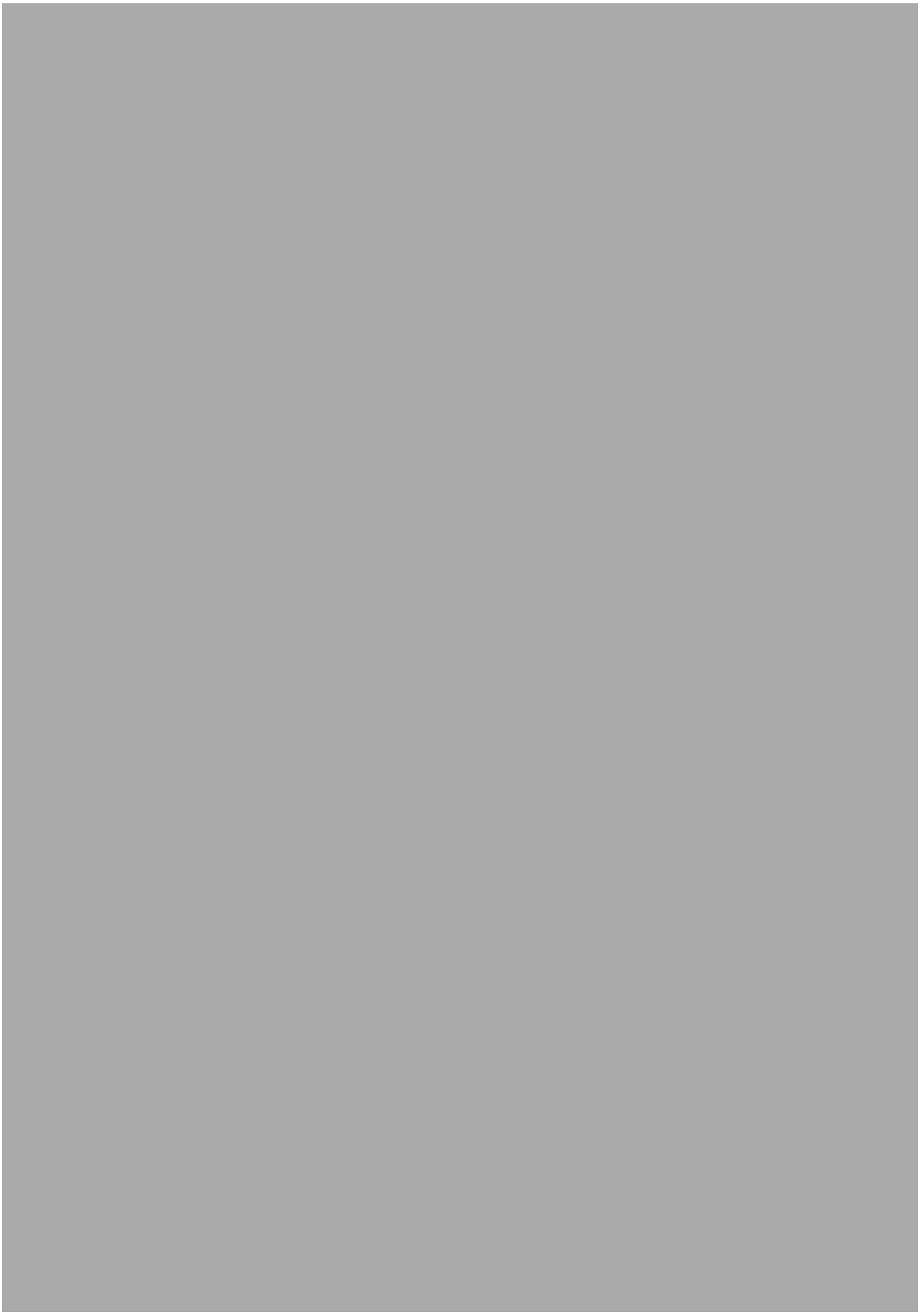


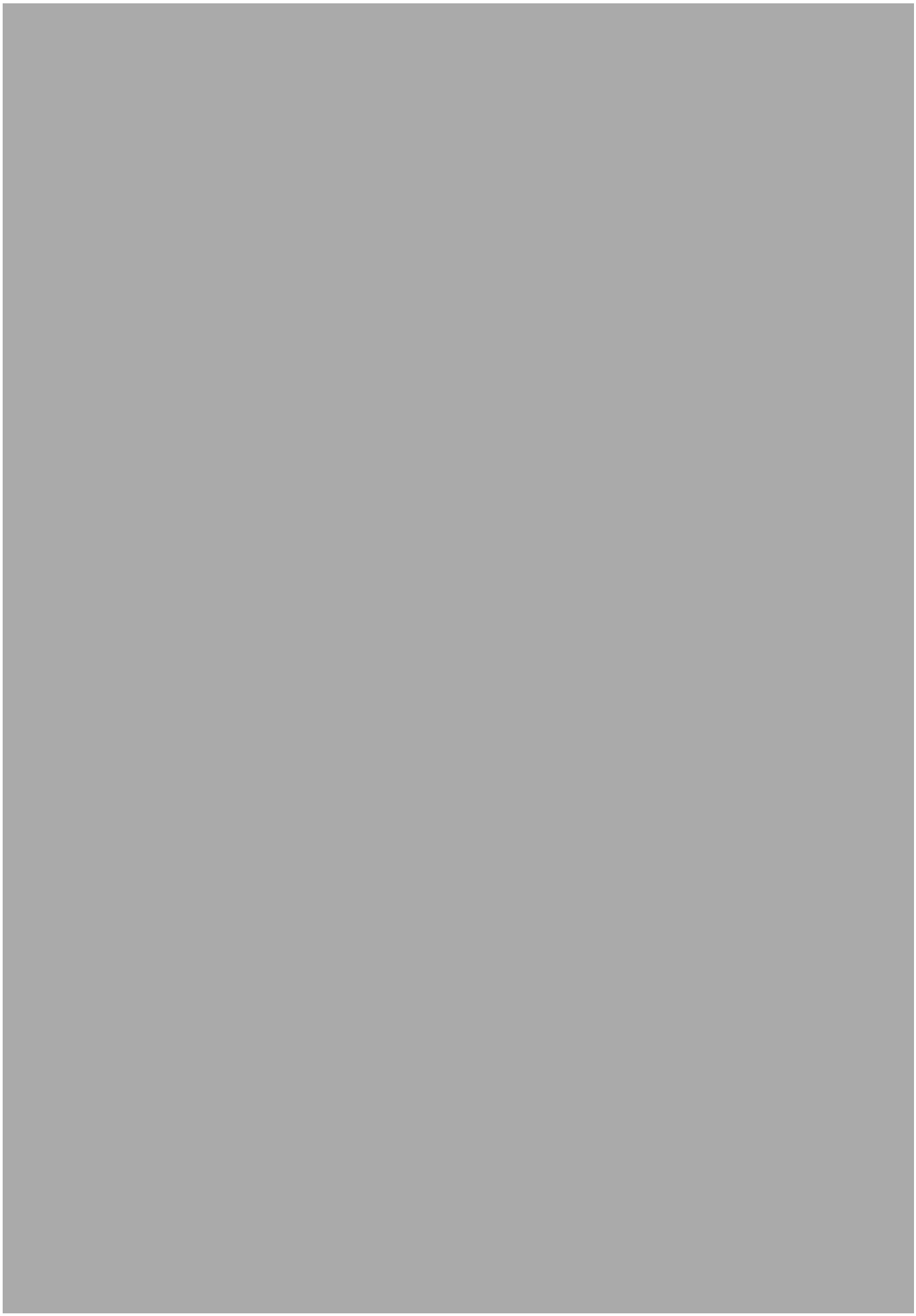


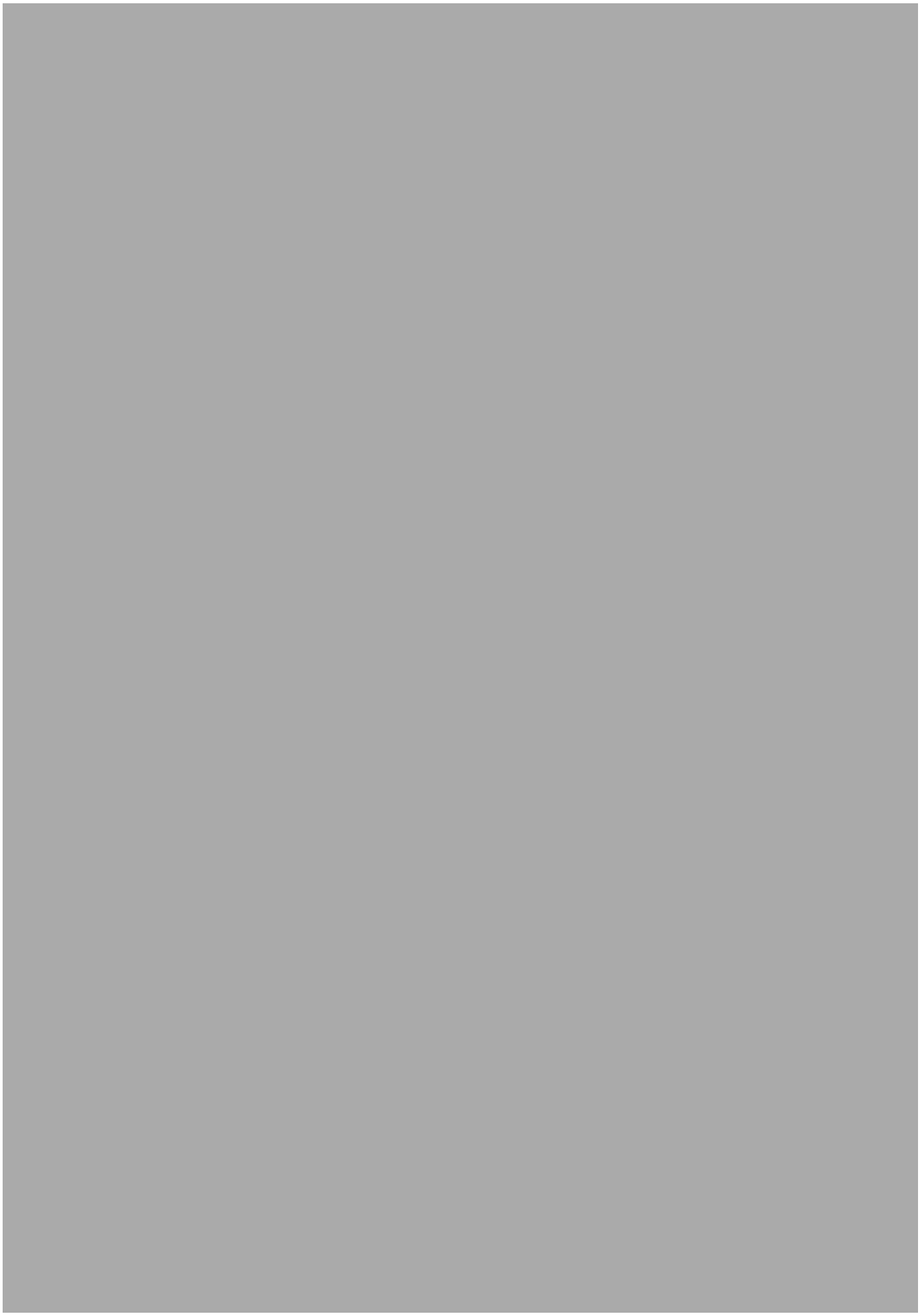


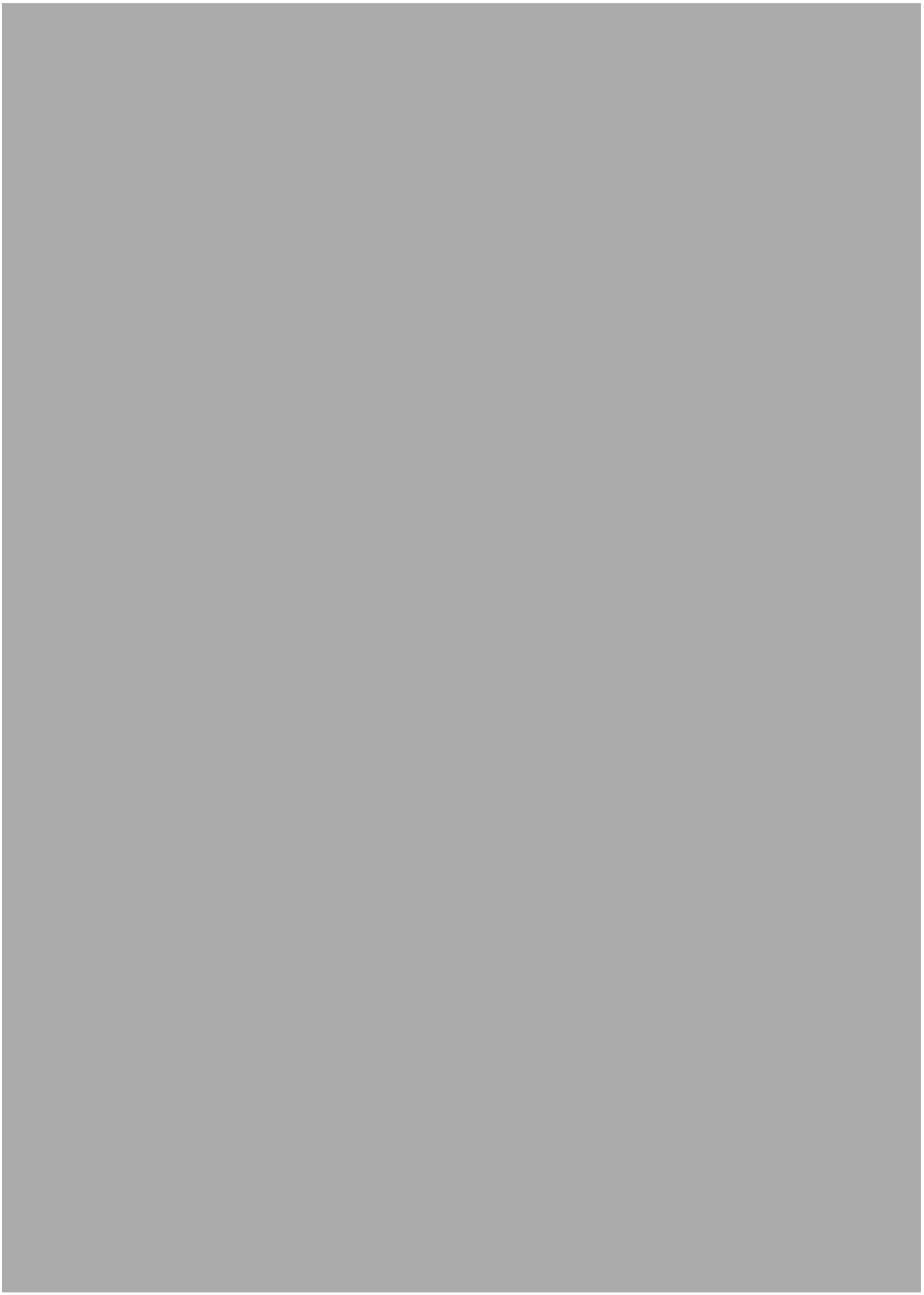


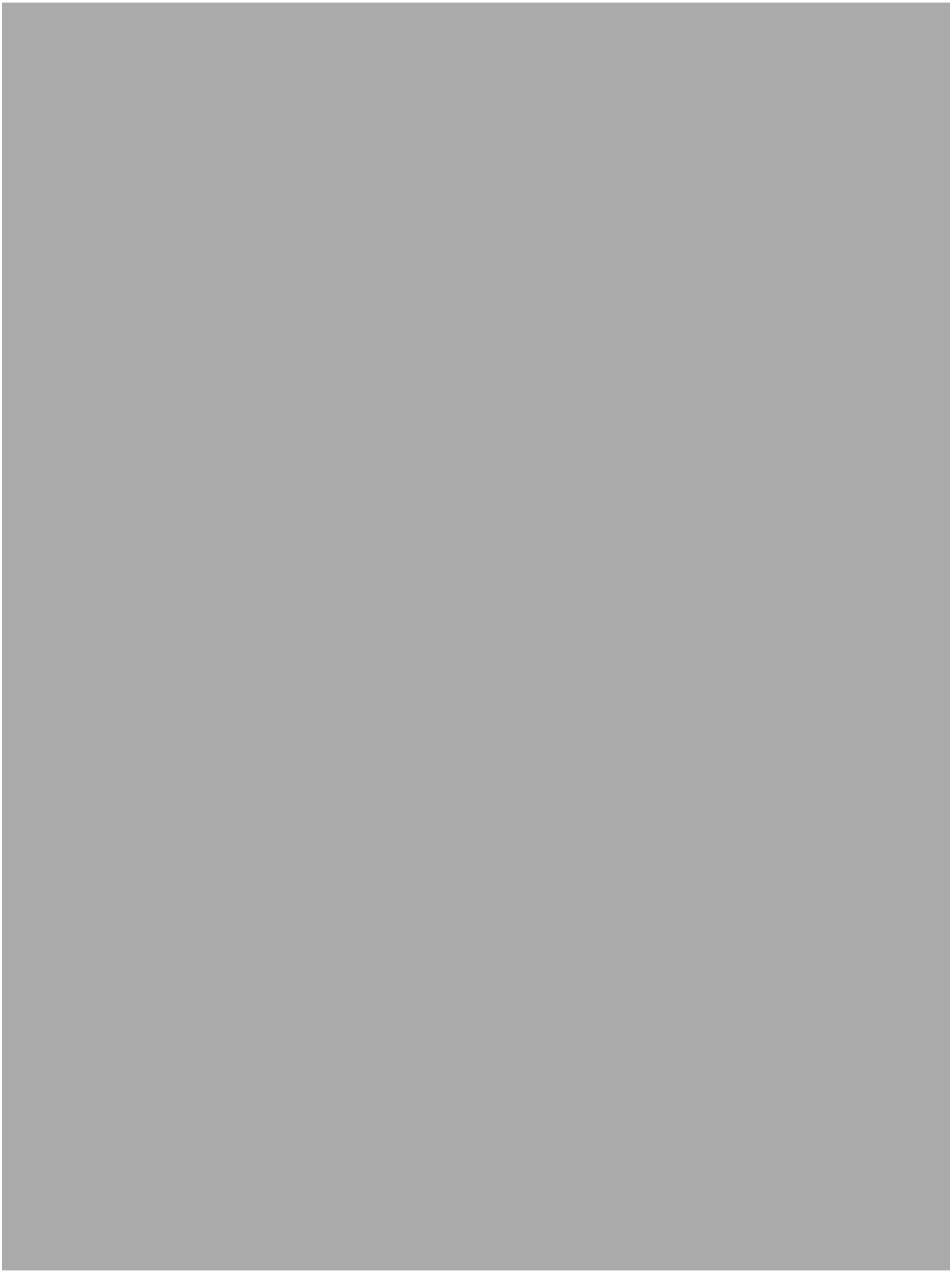


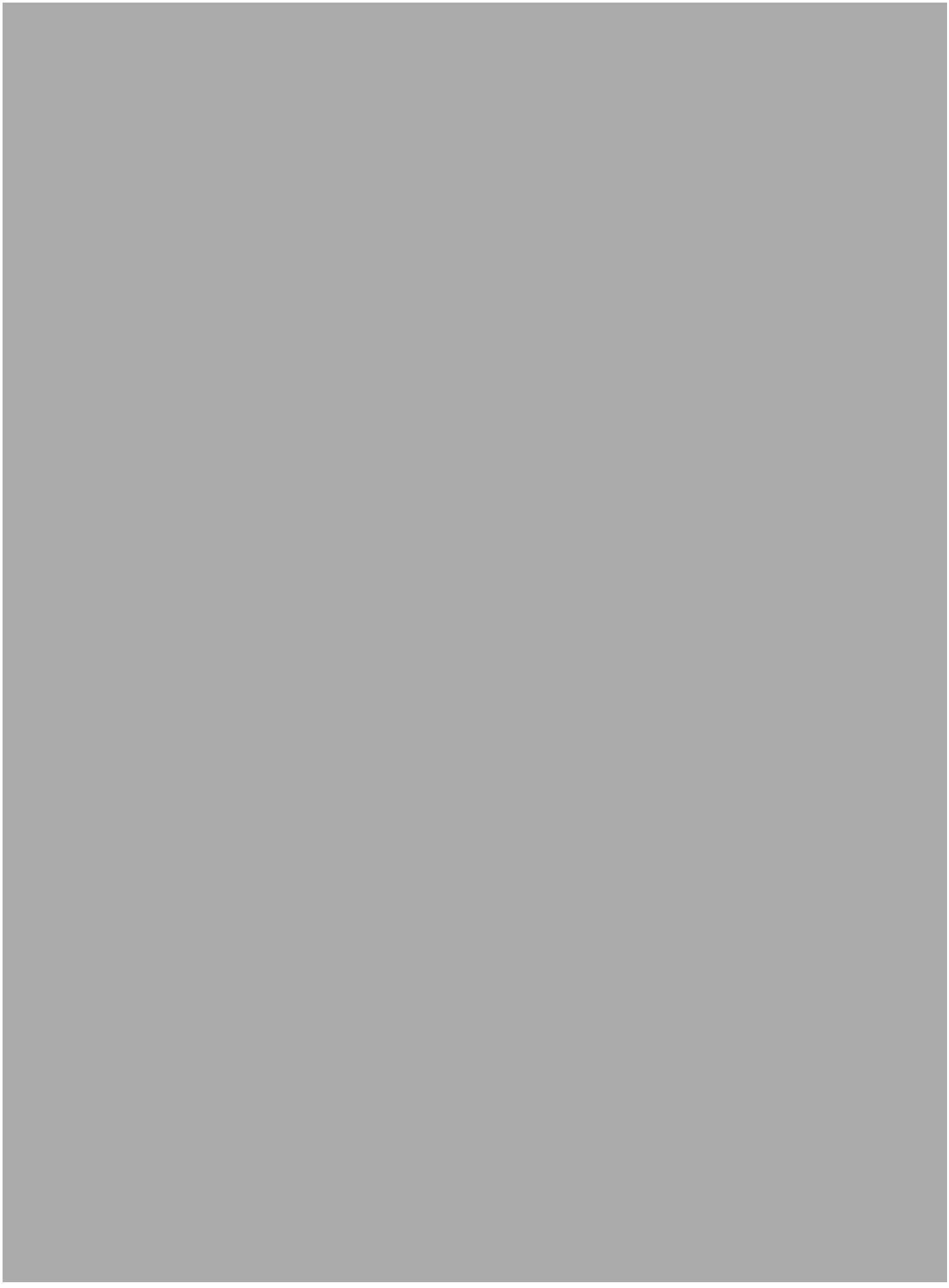


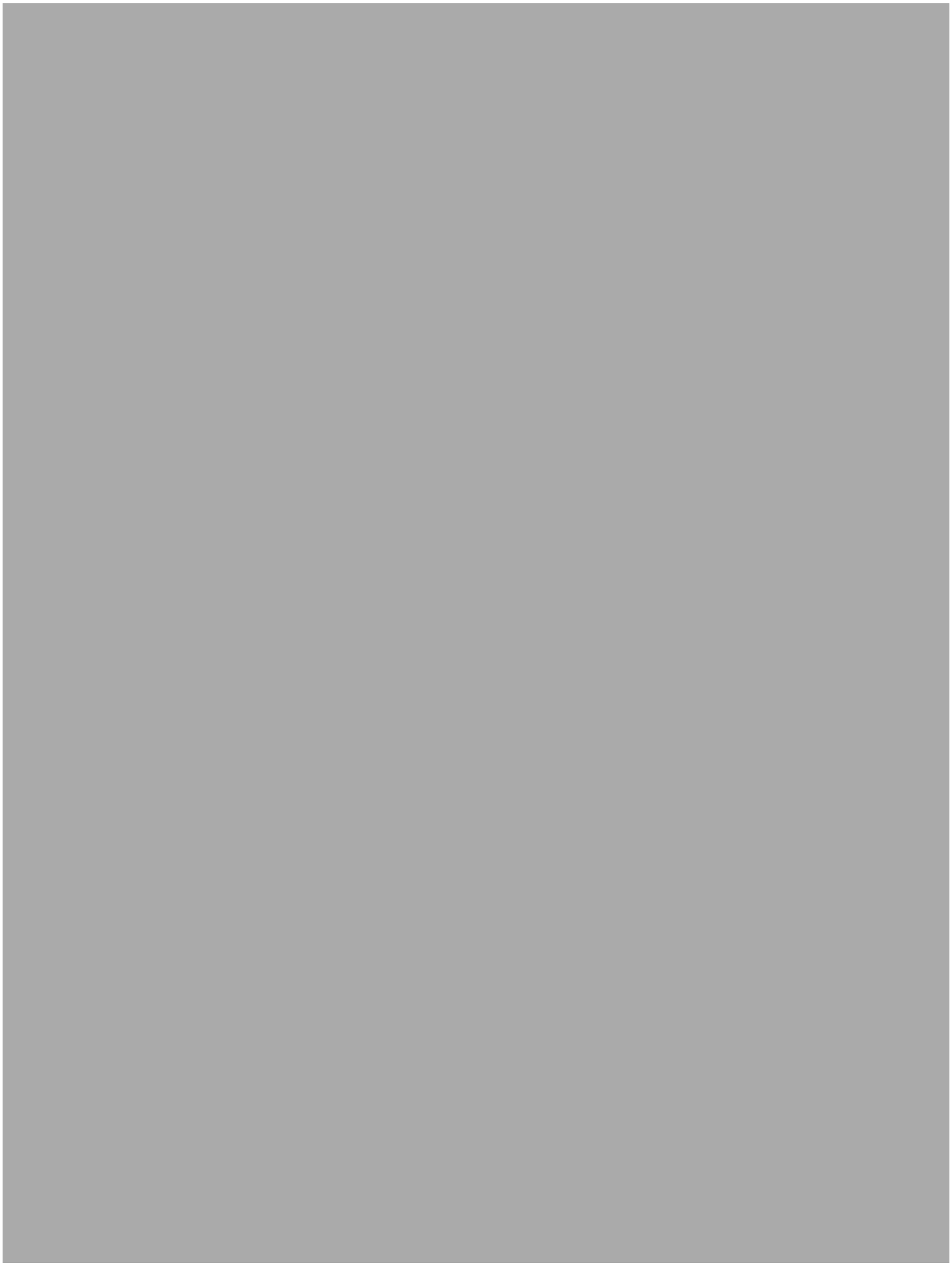












Time Period	Source	Stage A: Number of Firms in Source	Stage B: Number of TT Firms in Source	Stage C: Number of TT Manufacturers in Source
November 2011-March 2012	Fame Database: SIC: 1396	172	70	19
	UK 2011 TT Directory	215	50	11
	Internet Searches	35	32	5
	Technical Textiles Net Directory	135	20	0
	EMTA Directory	5	5	1
	LTMA Directory	37	4	4
	UKFT Directory	312	2	0
April - June 2012 (Placement)	NWtexnet Sources	624	72	17
	Skillset Website & Reports	5	2	0
	Industrial Specialist	18	1	2
	Techno Textiles 2 (2007)	4	4	0
	Twitter	1	1	0
	LinkedIn	3	3	3
	LinkedIn Recommendations	18	8	5
July 2012-October 2012	Composite UK Directory	164	3	0
	Crunchwear Website	2	1	0
	Europages Directory	43	15	0
	Ezilon UK Directory	12	1	0
	LOOK4TEXTILES Directory	7	1	0
	Scottish Enterprise Membership Directory	25	4	0
	Nonwovens Network Directory	130	20	3
	Free Index Directory	79	15	1
	Textiles Scotland Membership Directory	10	1	1
	UKTI: Textiles in Action (2012)	45	4	1
March – June 2013 (Data Collection)	Snowball (Companies)	4	4	1
	Snowball (PhD Colleague)	1	1	1
	Techtextil 2013 Exhibitor List	43	9	1
	Total of Firms Identified	**2147**	**353**	**76**

Source	Reference	Access Date
Textiles Scotland	http://www.textilescotland.co.uk/Find-a-Company.aspx	October 2012
Scottish Enterprise	http://apps.scottish-enterprise.com/search/supplierdirectorysearch.aspx?viewtreeid=167401	October 2012
Europages	http://textiles-clothing.europages.co.uk/business-directory-europe/did-17/hc-17511/Technical-textiles.html	October 2012
Look4Textiles	http://www.look4textile.com/6/default_3.htm	October 2012
Ezilon UK	http://find.ezilon.com/search.php?q=technical+textiles&v=uk	
Free Index	http://www.freeindex.co.uk/categories/industry/manufacturing/textiles(5)/	October 2012
UKTI 2012	Textiles in Action: A guide to UK performance Textiles, Published in June 2012 by UK trade & Investment, Crown Copyright. Available at: http://www.ukft.org/documents/industryinformation/Textiles%20in%20Action_web.pdf	October 2012
UKTI 2011	UK Technical Textiles Directory – UK Trade & Investment – Published May 2011 by UK Trade & Investment, Crown Copyright 2011. Available at: www.tikp.co.uk/download/?id=9	November 2011
NWtexnet Placement	Gained Membership directory whilst on placement. Had 2 company introductions. Conference attendance in UK and Europe - introductions to universities and companies.	June 2012
Investkonsult Sweden AB Nonwoven List	Hardcopy list from their own directory sent via email.	September 2012
Technical Textiles Executive Directory (Julian Ellis)	Technical Textiles Executive Directory (2005). Hard copy provided.	June 2012
Nonwovens Network UK	http://www.nonwovensnetwork.com/members.html -	October 2012
Technical Textiles Net	http://www.technical-textiles.net/section_links.htm	November 2012
Techno Textiles (Directory of Addresses – mentioned in book)	Techno Textiles 2: revolutionary fabrics for fashion & design, (2007) Sarah E. Braddock Clarke and Marie O'Mahony, UK Thames & Hudson Ltd. Directory of Addresses, 200-203	July 2012
Composites UK	http://www.compositesuk.co.uk/MembersDirectory/SearchCompanies.asp	October 2012
East Midlands Textiles Association Ltd	6 companies were identified from their own database.	December 2011
Crunchwear	http://www.crunchwear.com/	October 2012
Rigby Associates (Year)	Rigby Associates report provided from NWtexnet placement.	June 2012
Skillset	Members on the Fashion and Textiles Skills Council.	June 2012
LinkedIn Groups	6 firms responded and 3 companies identified to interview.	July 2012



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School of Management,
Department of Strategy and International Business,
Birmingham Business School,
University of Birmingham,
Birmingham
B15 2TY
[Insert Date]

R.E: Participation in Manufacturing Discussion

Dear [Insert Full Name],

I am writing to ask for your contribution to a research project at the University of Birmingham on the innovation and competitiveness of UK manufacturers involved in technical textiles.

I am currently undertaking a large survey of technical textile companies in the UK and this research is the first major piece of social science research on this industry.

As part of this survey, I would like to interview yourself about **[Insert Company Name]** as this would be greatly beneficial to my research. As you are aware manufacturing has been sidelined in the political agenda in recent years. I believe we need to change the perception of manufacturing; this research will be used to teach students at universities and schools across the UK the opportunities in manufacturing today as well inform the political agenda on manufacturing.

The interview will take approximately 40 minutes and can be conducted at your convenience. In return for your participation, I am able to provide you with a resourceful sectoral analysis of the UK textile industry in 2014, which will be informed and understood by this project and other research in the field of geography. This project aims to recruit 50 firms and all firms involved will remain anonymous throughout the research process for this purpose. Please note, there is an information booklet attached that contains further benefits and details on this project.

I hope you are interested in being part of this topical research, and perhaps I can contact yourself in a couple of weeks to discuss this further. In the meantime, if you have any enquiries about this research project, please do not hesitate to contact myself.

Yours Sincerely,

Megan Ronayne
Doctoral Researcher

Mobile: [Insert Contact Number] Email: [Insert Email Address]

June 2013



UNIVERSITY OF BIRMINGHAM

The Innovativeness & Competitiveness of UK Technical Textile Manufacturers

Principal Investigator: Megan Ronayne (PhD Researcher)

UNIVERSITY OF BIRMINGHAM

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Participant Information Booklet

1.0	**Working Title of PhD:** Manufacturing Textile Futures: Innovation, Competitiveness and the Evolution of UK Technical Textile Firms
1.1	**Start Date:** 26 September 2011 **End Date:** 23 December 2014
1.2	**Project Background:** Megan Ronayne is undertaking funded PhD research to develop an understanding on how UK textile manufacturing companies have survived, evolved and maintained their competitive position in a global economy. The project aims to investigate the relationship between the innovativeness of technical textile manufacturing firms and their competitiveness. This project is part of a much larger research programme at the University of Birmingham that is emphasising the competitive dynamics of manufacturing in the UK and elsewhere. The project is currently undertaking a large survey of technical textile companies in the UK and this research is the first major piece of social science research on this industry. It is expected that this project will develop a more accurate and updated understanding on manufacturing in the UK today which can then be used to inform the political agenda on manufacturing and teach students at universities and schools about the importance of manufacturing to the UK economy and the possible opportunities for young people.
2.0	**Invitation to Participate:** I would like to invite you to participate in this PhD research at the University of Birmingham. Your participation would involve a short discussion about your company: • The discussion can be conducted at your convenience either a company visit or over the telephone; • The discussion will last for approximately 40 minutes and audio recorded; • Please note participation in this interview is voluntary and you are free to withdraw from this research project up until September 2013 (please refer to 2.7).
2.1	**Recruitment of Participants:** • The project aims to recruit between 40 and 60 technical textile manufacturing companies; • The companies identified are manufacturers of fabric for a technical textile application through any through any method (weaving, knitting, spreading, bonding, crocheting etc); • The location of companies involved in this study are UK wide; • The companies have been selected from a list of company names constructed by the investigator from over 20 public directory sources & the Fame database.

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Participant Information Booklet

2.2	**Benefits:** In return for your participation, a sectoral report containing the analysis and results of this project will be provided. This report will be informed and understood by the PhD research, current research at the University of Birmingham and other research in the field of geography. The current 25 technical textile firms involved in the project have informed the investigator that the discussion that occurs during the interview to be beneficial for the company to reflect on the firms' current activities. Your company will be part of a large survey of technical textile manufacturers and involved in the first major piece of social science research on this industry. From the results on the project, the company will gain an understanding on the different survival pathways of firms, current challenges and competitive strategies other firms are using for the future. The company will gain access to any academic literature on the sector in the social sciences; there is currently one academic paper and book chapter written by the investigator on technical textiles and the UK Carpet Industry.
2.3	**Deliverables:** • I will keep you up to date regularly with the progress of this project via email or telephone; • You may request to access the interview transcript under the Freedom of Information Act, 2000; • A sectoral report will be provided to yourself and the company at the end of the project (see 2.8); • All data collected from company interviews as well as previous data collected from discussions with key academics and trade bodies of technical textiles will contribute towards the overall analysis; • I will also attempt to publish academic papers from the main conclusions of the thesis; • The project will improve my research and professional skills for future research and career development as well as contribute valuable knowledge to academic theory & policy.
2.4	**Confidentiality:** • All data will be treated anonymously and confidential. Your personal details will not be disclosed to any other organisation as stated under the Data Protection Act 1998; • To ensure anonymity, all companies will be assigned a randomised number between 1 and 100, for example company 72. If there are multiple participants in an interview they will then be labelled 72.1 and 72.2 for example. The company will be labelled this number in the interview transcript and all documents of the company. The companies will also be presented as their company number throughout the written thesis. Names of individuals will also be changed and locations mentioned in interviews will also be changed or not written into the transcripts. I will be the only person who will know the details of each company through a password protected document on my personal laptop; • The project supervisors and myself will be the only individuals who will have access to the data; • The data will be recorded on a Dictaphone and then transcribed by myself. The transcripts will be used for only analysis purposes; • The research data will be stored on password-protected documents on my personal laptop. Hard copies of data will be secured in a lockable filing cabinet in the Investigators' home office and not

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Participant Information Booklet

	at University Premises. • The data will be retained by myself and will be accessible for 10 years in accordance *with current university guidelines and guidance from the UK Research Councils.* • After the 10-year period the data will be destroyed (deleted from ICT systems and any hard copy data will be shredded).
2.5	**Informed Consent Form:** • A consent form is provided at the end of this booklet to obtain valid consent; • The consent form details all the research interventions which should be discussed with myself before any research is undertaken; • This information sheet informs the consent form, if there is anything you do not understand or have any further enquiries about the project please seek further clarification prior to participating; • Once we have agreed on the points of the consent form, two copies of the form are signed in which one copy is kept by myself.
2.7	**Participation Withdrawal:** • Participation to this project is voluntary and you have the right to withdraw from the project until **September 2013** without giving any reason; • If you decide to withdraw from the project, please send an email to myself with Professor John Bryson cc'd into the email; • If you do withdraw from the project, your data will be removed from the study and destroyed and you will not receive any compensation offered.
2.8	**Timescale of Project:** **January-October 2013:** Recruitment of companies and undertaking interviews with companies; **October 2013-Dec 2014:** Analysing and interpreting data and writing up of thesis; **December 2014:** Hand in draft of thesis; **March 2015:** Sectoral Report delivered to companies.
2.9	**Funding Body of Study: ESRC** This PhD Project is funded by the **Economic & Social Research Council (ESRC).** The ESRC is the 'UKs largest organisation for funding research on economic & social issues'. They support independent, high quality research, which has an impact on business, the public sector and third sector. This research project was awarded funding in August 2010, I firstly completed my masters training in research before undertaking this PhD project in September 2011. **Webpage:** http://www.esrcsocietytoday.ac.uk/ **General Enquiries:** [redacted]

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Consent Form

PhD Project Title: *Manufacturing Textile Futures: Investigating the Competitive Dynamics of UK Technical Textile Manufacturers.*

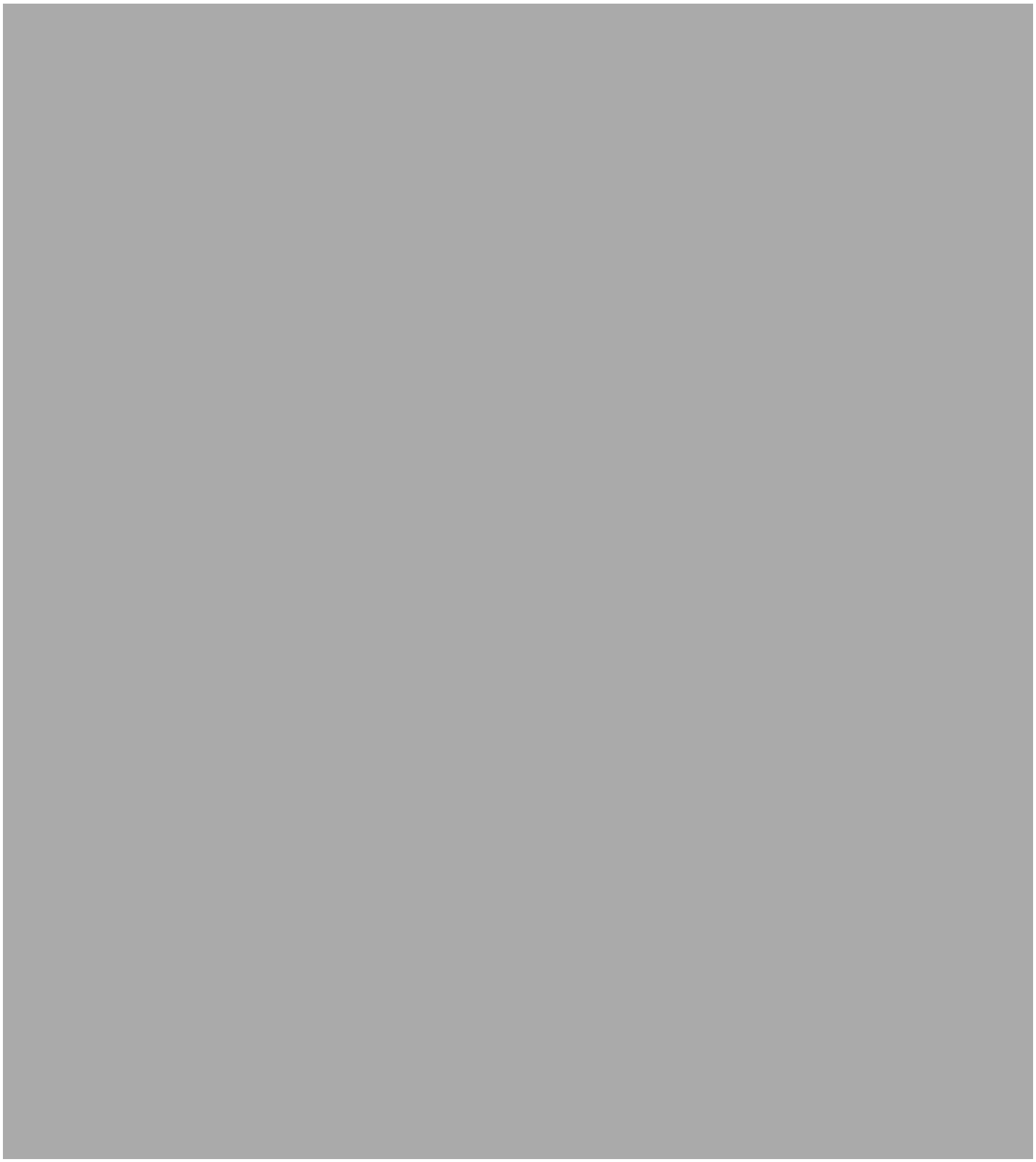
Principal Investigator: *Megan Ronayne (BA; MSc)*

This information is being collected as part of a research project concerned with the competitiveness of UK Technical Textile Manufacturers by the School of Geography in the University of Birmingham in collaboration with the Economic and Social Research Council (ESRC). The information which you supply and which may be collected as part of the research project will be transcribed into transcripts and entered into a database by the principal investigator. The data will only be accessed by authorised personnel involved in this project (refer to page 5 of booklet). The information will be retained by the main investigator and will only be used for research purposes. By supplying this information you are consenting to the main investigator storing your information for the purposes stated above. The information will be processed in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

Statements of Consent:	***Please tick box***
1. I confirm that I have read & understood the participant information sheet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.	☐
2. I understand that my participation is voluntary & I am free to withdraw up until September 2013 without giving any reason. *If I withdraw my data will be removed from the study and will be destroyed.*	☐
3. I understand that this data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998. I also understand data will be preserved and accessible for 10 years in accordance with current university deadlines	☐
4. Compensation arrangements have been discussed with me (ie. Sectoral Report)	☐
5. I understand that this interview will be audio recorded and have notified the researcher if I do not wish for the interview to be audio recorded	☐
3. I understand that all data will be treated as confidential; your personal details will not be disclosed to any other organisation as stated under the Data Protection Act 1998.	☐
5. Based upon the above, I agree to take part in this study	☐

	Name (Please Print)	***Signature***	***Date***
Participant			
Investigator	*Megan Ronayne*		

Investigators' Profile: Megan Ronayne



<table>
<tr><td colspan="2">Conversation 1: Company Background
Please could you tell me what this company does and it's history?</td></tr>
<tr><td rowspan="3">C1
Topics</td><td>Company Background:
Year the company was established
Turnover & Profit Levels (remained steady?)
Challenges – What have been the main challenges for the company in recent years? How did the company respond?
Has there been any Merges or Acquisitions? Who initiated? Why? What was the impact?</td></tr>
<tr><td>Interviewee:
Could you tell me a little bit about yourself and your position in this company?</td></tr>
<tr><td>Products:
What are the core products produced at this site? (End product? Technical? Length of Product?)
Are there any novel products produced at this site?
Are there any services attached to the product range?
Large product portfolio:
Has the company always produced a large product portfolio? If no, how have they managed to develop a large product portfolio?</td></tr>
<tr><td colspan="2">Conversation 2: Production Process
Please could you talk me through the process of producing a standard product from what happens when an order comes in to delivery? And then could you do the same for a novel product?</td></tr>
<tr><td rowspan="6">C2
Topics</td><td>Skills:
Number of employees & how many are on the shop floor?
What are the core skills and functions required at the different stages of the production process?
Over the last 10 years has your workforce had to become more skilled?
Are there any hard to fill vacancies? Is this company implementing a succession management plan by training their workforce? For example recruiting apprenticeships or mechanizing production?</td></tr>
<tr><td>Suppliers:
Who are your suppliers?
Where are they based?
What is your relationship like with your suppliers [length of relationship] & how do you work with them?</td></tr>
<tr><td>Location:
Are there multiple production sites?
Are any of the products made off site? E.g. outsourced to another company?</td></tr>
<tr><td>Production:
Which part of the production process is the most critical and why?</td></tr>
<tr><td>Customers:
What markets is the company in? How did the company enter this/these markets?
Who & where are your customers? [Location near a particular type of customer]
What is your relationship like with your customers [length of relationship] & how do you work with them? [Any specific interactions & changes]
How does the company acquire these customers? [Due to location/ relationships?]
Does the company have a key customer in terms of production; turnover; influencing change?
Does this company export? How big is your export market compared to their domestic market?</td></tr>
<tr><td></td></tr>
</table>

Conversation 3: Changes in the Company Please could you talk me through any changes in or to the company? What have been the three most important improvements in the company? (Where & How?)	
C3 Topics	***Where & when have there been changes?*** • [Product; Process; market; employment; organisation of the company; location; competition; interaction with companies and supply chain; supply chain; methods of working; shop floor; office; technological]
	Why have there been changes? • Due to internal or external reasons? For example, changes in consumption or changes in the supply chain?
	Who or what have been the source of these changes? • Universities: to help develop products; A knowledge transfer partnership? [who initiates placement] • Interaction with outside companies: Who? [Customers; suppliers; competitors] When? [Within or outside projects] Location of these companies? Why? [Bring niches or technology together] Type and length of relationship? Who funds co-innovation or projects? • Key People within the Company: Has there been any key people within the firm that has brought about change? Who? How? • Knowledge: How has the company acquired new information, which has enabled the company to make these changes? Ie. Responding to customers supply chain or products? Where does their inspiration come from for management practices, product and/or process changes? Acquire learning inside or outside the UK? • Decisions: Has anyone outside the company introduced a change in working practices? Production line or product? E.G Any technologies been combined together? What decisions have been made – who's influenced these decisions?
Conversation 4: Competition	
C4 Topics	***Competitors:*** • Who are your competitors and why? [Location of Competitors] • Have there been any collaborations with competitors? [Joint Ventures] ***Competitive Advantage:*** • What differentiates this company to your competitors?
Conversation 5: Risks & Opportunities	
C5 Topics	**Opportunities:** • What opportunities are there for the company at the moment? **Risks:** • Are there any risks facing the company at the moment? Are there any risks for the company in the future, which would undermine their current position? • What strategies are the companies pursuing to respond to these risks?
Conversation 6: **Could you talk me through this company's position in the technical textile sector?**	
C6 Topics	**Position in the Sector:** • Does this company identify themselves as part of a technical textile sector? • How & when did the company begin producing technical textile products? (An adaptation from increasing competition or growth of companies based in lower cost locations?) • How did the company align itself as part of 'technical textiles'? • What proportion of the business is to do with Technical Textiles? • Does the company interact with research in the sector? Projects?

Interview Reflection 1

Company: [redacted] **Interviewee:** [redacted] **Date:** 19/2/13.

1st Interview.

Overall Reflection:

* This was the first interview in [redacted] of this company. My first reaction was of how short (in time) the interview was between myself & [redacted].
  → Need to reflect on transcript & see what questions were missed & then revisit the firm with these Q.
  → Also reflect on the responses to particular Q & my way of asking the Q & see if this had any effect on the answer.

* The company was a relatively young company - set up in [redacted] & this actually D the answers to the Q as they've not had a 'stepped' evolutionary process but are only 4yrs or 4yrs.

* I didn't get much from him on discussing the Product Process but more became clear once we went round the factory
  → I think the by issue with the Q currently is they don't have the A+O info I'm trying to get - so I'm not sure if I'm getting enough in-depth info.

* The company was also on quite a large site - but in separate units across the Product Process.

Interview Reflection 1

Reflection on Interview Questions:

* Don't feel that Product Process Q is very I feel they answer some of this in Conscious one.
* Difficult when asked about skills - need to lead onto somewhere this Q doesn't make sense why. im asking this
* I think more Q on local needs Adj → DRCQ
* There is nothing asking at a Manager or DM or work Practice.

What questions do I still need answering:

Research Development:

* Research Q will have to be D - consider from survey data & discuss with [redacted]

Interview Reflection 2 - During Transcription

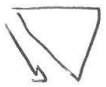
Company: [redacted] **Interviewee:** **Date:**

Reflection Notes:

[redacted]

- With this interview I tried to go in being a bit naive about the company, & not dig any R before. However, I think this approach annoyed the company as I 'wasn't bothered' to do my research before - I also forgot & did not explore active listening as well as I should had done & Questioned twice which type of textile they were 'ie/ skirt body'

- Asked 'Has there been any challs' perhaps too early on in the interview.
  → Covered company background & her straight into challs.
  & should have gone to what do they do & Product Process



- decitex. - Mass in Grams per 10,000 metres.

- Product Process Q - I wasn't clear enough about what I wanted to discuss - Ask could you walk me through ... her Ask for a recent Product.

- I think maybe I jumped in with too many Q & not living enough - so asked a Q but then moved onto another & this caused a diversion (↓) in the Answers the participant gave
  → Remember to let them speak - have a note of Q & Ask at the end of a late dot - Natural.

For too much interrupt

* Remember is a preliminary interview - i.e. her list - & follow up with Q missed.

- I'm not expand on the info. the participant gave me but jumped onto the next Q Quest.

* I think I'm a bit leading Q - I ask on the Q expecting similar Answers to be confirmed knowledge I have from other companies → need to stay open

* I haven't expanded on any Point!

Further Enquiries: Company [redacted]

Further enquiries/actions with the company:

* follow up Q.
* Need to do summary sheet & Analyse transcript.

Further enquiries/actions with a specified organisation or person:

[redacted] has been Recomend → will [redacted] Make Contact.

Further enquiries/actions with the research project: * All tweed machinery.

* Also of R+D labs in the company seem to have international stakes from Europe. Europe have a better foothold & try in technical textile?

* All the carbon fibre company are doing similar things ie/ Automotive (low Margin) - what the new high Margin company all be?

* the survival of HAND
  → Red tape - Policies & Taxes on Mawby
  → look at Policy + Taxes Thesis - Brexit effect of work for company

* May on go to China to visit to choose Raw Material - No Raw Material in the U.K.

Appendix G: Characteristics of 40 UK TT Firms Interviewed

Identification Code	Date Interviewed	No. of Interviewees	Interviewee 1 (Role)	Interviewee 1 Gender	Interviewee 2 (Role)	Interviewee 2 Gender	Interviewee 3 (Role)	Interviewee 3 (Gender)	Length of Interview (minutes)	Face-to-face (F2F) / PHONE	Location of Interview (Region)	Factory Tour	Nwtexnet Member	Access Method
N-S-Knitter-2	01.08.2013	**1**	Business Manager	Male	NA	NA	NA	NA	122	F2F	East Midlands	YES	NO	Email
E-M-[Narrow]Weaver-4	03.09.2013	**1**	Operations Director	Male	NA	NA	NA	NA	100	F2F	West Midlands	NO	NO	Snowball
N-L-Weaver-5	04.09.2013	**2**	Operations Director	Male	Technical Director	Male	NA	NA	124	F2F	North West	NO	YES	Nwtexnet
E-M-[Narrow]Weaver-5	05.07.2013	**2**	Managing Director	Male	Operations Director	Male	NA	NA	99	F2F	East Midlands	YES	NO	Email
E-M-[Narrow]Weaver-7	08.08.2013	**2**	Managing Director	Male	Operations Director	Male	NA	NA	113	F2F	East Midlands	YES	NO	Snowball
N-M-[Narrow]Weaver-2	09.08.2013	**1**	Business Manager	Male	NA	NA	NA	NA	41	PHONE	Wales	NO	NO	Snowball
E-S-Knitter-6	1.03.2013	**1**	Managing Director	Male	NA	NA	NA	NA	66	PHONE	Northern Ireland	NO	NO	Email
E-S-Nonwoven-5	10.07.2013	**1**	Managing Director	Male	NA	NA	NA	NA	53	F2F	North West	NO	YES	Nwtexnet
E-S-Nonwoven-4	11.07.2013	**2**	Managing Director	Male	Operations Director	Male	NA	NA	60	F2F	Yorkshire & the Humber	NO	NO	Email
E-M-Weaver-12	12.08.2013	**1**	Business Manager	Male	NA	NA	NA	NA	47	PHONE	North West	NO	YES	Snowball
E-S-Knitter-7	13.03.2013	**1**	Managing Director	Male	NA	NA	NA	NA	120	F2F	North West	YES	NO	Email
E-M-Weaver-11	13.06.2013	**1**	Technical Director	Male	NA	NA	NA	NA	120	F2F	North West	NO	YES	Email
E-S-Weaver-6	13.06.2013	**1**	Managing Director	Male	NA	NA	NA	NA	92	F2F	North West	YES	YES	Email
E-M-Weaver-7	14.08.2013	**1**	Sales Director	Male	NA	NA	NA	NA	115	F2F	South West	NO	NO	Email
E-M-Bobbinet-1	15.05.2013	**1**	Sales Director	Female	NA	NA	NA	NA	130	F2F	South West	NO	NO	Email
N-M-Nonwoven-1	15.08.2013	**1**	Managing Director	Male	NA	NA	NA	NA	71	F2F	West Midlands	YES	NO	Email
E-S-Weaver/ Knitter-1	17.04.2013	**1**	Managing Director	Male	NA	NA	NA	NA	78	F2F	Scotland	NO	NO	Email
E-M-[Narrow]Weaver-6	17.05.2013	**1**	President	Male	NA	NA	NA	NA	53	PHONE	South West	NO	NO	Email
E-M-Weaver-9	17.07.2013	**1**	Managing Director	Male	NA	NA	NA	NA	155	F2F	North West	YES	YES	Email
E-S-Weaver-3	17.10.2013	**1**	Sales Director	Male	NA	NA	NA	NA	39	PHONE	Yorkshire & the Humber	NO	YES	Cold Called
E-M-Knitter-4	18.06.2013	**1**	Managing Director	Male	NA	NA	NA	NA	125	F2F	East Midlands	YES	NO	Email
E-S-[Narrow]Weaver/Knitter-2	18.06.2013	**1**	Managing Director	Female	NA	NA	NA	NA	38	F2F	East Midlands	NO	NO	Cold Call
N-M-Nonwoven-2	19.02.2013	**1**	Managing Director	Male	NA	NA	NA	NA	45	F2F	East Midlands	YES	NO	Email
E-M-Nonwoven-7	19.08.2013	**1**	Managing Director	Male	NA	NA	NA	NA	168	F2F	North West	YES	YES	Email
E-M-Nonwoven-3	2.10.2013	**1**	Technical Director	Male	NA	NA	NA	NA	59	PHONE	North West	NO	NO	Email
E-M-Weaver-10	20.08.2013	**1**	Managing Director	Male	NA	NA	NA	NA	97	F2F	Yorkshire & the Humber	NO	NO	Email
N-M-Weaver-4	20.08.2013	**1**	Managing Director	Male	NA	NA	NA	NA	63	F2F	Yorkshire & the Humber	NO	NO	Email
E-M-[Narrow]Weaver-1	21.03.2013	**1**	Managing Director	Male	NA	NA	NA	NA	155	F2F	East Midlands	YES	NO	LinkedIn
N-M-Weaver-1	21.09.2012	**1**	Operations Director	Male	NA	NA	NA	NA	96	F2F	North West	NO	YES	Nwtexnet
E-S-Knitter-5	22.02.2013	**1**	Managing Director	Male	NA	NA	NA	NA	142	F2F	East Midlands	YES	YES	Nwtexnet
E-M-Weaver-8	22.04.2013	**1**	Operations Director	Male	NA	NA	NA	NA	99	F2F	Scotland	YES	NO	Email
E-M-Weaver/Nonwoven-1	23.04.2013	**1**	Managing Director	Male	NA	NA	NA	NA	77	F2F	Scotland	YES	NO	Email
E-M-Weaver/Knitter/Nonwoven-1	24.04.2013	**1**	Business Manager	Female	NA	NA	NA	NA	119	F2F	Scotland	YES	NO	Email
E-M-Weaver-2	24.09.2012	**1**	Operations Director	Male	NA	NA	NA	NA	122	F2F	North West	YES	YES	LinkedIn
E-S-Nonwoven-6	25.04.2013	**1**	Sales Director	Female	NA	NA	NA	NA	56	F2F	Scotland	YES	NO	Email
E-L-Knitter-8	25.06.2013	**3**	Managing Director	Male	Sales Director	Male	Operations Director	Male	129	F2F	East Midlands	YES	NO	Email
N-S-Knitter-1	25.09.2012	**1**	Managing Director	Male	NA	NA	NA	NA	60	F2F	East Midlands	YES	NO	LinkedIn
E-M-[Narrow]Weaver-3	28.05.2013	**1**	Managing Director	Male	NA	NA	NA	NA	125	F2F	North West	YES	YES	Snowball
E-M-Weaver/Nonwoven-2	4.10.2013	**1**	Sales Director	Male	NA	NA	NA	NA	47	PHONE	Yorkshire & the Humber	NO	NO	Nonwoven Conference
E-M-Knitter-3	5.03.2013	**1**	Managing Director	Male	NA	NA	NA	NA	118	F2F	North West	YES	YES	Email

Appendix G: Characteristics of 40 UK TT Firms Interviewed

Identification Code	Year of Incorporation	Entry to TT Period	Production Type	Size of Firm	New or Established Firm	Employees	Ownership (Country)	Ownership Type	Single or Multiple Site	Detail on Multiple Site
E-S-Nonwoven-6	1973	1980s	Nonwoven	Small	Established	38	UK	Private Limited	Multiple	2nd Production Site in Sri Lanka
E-M-Weaver-11	1895	1950s	Weaving	Medium	Established	110	USA	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-Weaver-10	1783	1970s	Weaving	Medium	Established	165	UK	Family (7th Generation)	Single	NA
E-L-Knitter-8	1946	1960s	Knitting	Large	Established	390	USA	Large Corporation (Fortune 500 Company)	Multiple	Subsidary of Large International Corporation
E-M-[Narrow]Weaver-5	1795	1960s	Weaving (Narrow)	Medium	Established	81	UK	Private Limited	Multiple	2nd Production Site in UK
E-S-Weaver-6	1862	1970s	Weaving	Small	Established	28	UK	Family (6th Generation)	Single	NA
E-S-Nonwoven-5	1939	1970s	Nonwoven	Small	Established	45	UK	Family (2nd Generation)	Single	NA
N-L-Weaver-5	1985	1980s	Weaving	Large	NEW	260	Sweden	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-Nonwoven-3	1845	1980s	Nonwoven	Medium	Established	95	UK	Private Limited	Multiple	2nd Production Site in UK
E-M-Weaver-9	1858	1990s	Weaving	Medium	Established	109	Switzerland	Private Limited	Single	NA
N-M-Weaver-4	1950	1950s	Weaving	Medium	NEW	90	UK	Family (3rd Generation)	Multiple	3 Production Sites in UK
E-S-Knitter-6	1915	1990s	Knitting	Small	Established	40	UK	Private Limited	Single	NA
E-M-Weaver/Nonwoven-2	1955	1990s	Weaving & Nonwoven	Medium	Established	200	UK	Private Limited	Single	NA
E-M-Weaver-8	1666	1990s	Weaving	Medium	Established	150	Sweden	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-[Narrow]Weaver-4	1942	1990s	Weaving (Narrow)	Medium	Established	75	The Netherlands	Private Limited	Multiple	Subsidary of Large International Corporation
E-M-Bobbinet-1	1895	1980s	Bobbinet	Medium	Established	55	Switzerland	Private Limited	Multiple	Subsidary of Large International Corporation
E-S-Knitter-5	1831	1960s	Knitting	Small	Established	45	UK	Family (4th Generation)	Multiple	2nd Production Site in UK. 3rd Production Site in Poland
E-M-Knitter-4	1888	1980s	Knitting	Medium	Established	75	UK	Family (3rd Generation)	Single	NA
E-S-Knitter-7	1985	2003	Knitting	Small	Established	38	UK	Private Limited	Single	NA
E-M-Weaver-7	1756	1940s	Weaving	Medium	Established	140	German	Group Limited	Multiple	Subsidary of Large International Corporation
N-S-Knitter-2	1988	1980s	Knitting	Small	NEW	13	UK	Private Limited	Multiple	Subsidary of Large International Corporation
E-S-Nonwoven-4	1976	2000s	Nonwoven	Small	Established	13	UK	Private Limited	Single	NA
E-M-[Narrow]Weaver-6	1665	1970s	Weaving (Narrow)	Medium	Established	220	USA	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-Weaver/Nonwoven-1	1868	1950s	Weaving & Nonwoven	Medium	Established	90	UK	Family (6th Generation)	Multiple	2nd Production Site in China
E-M-[Narrow]Weaver-3	1976	1980s	Weaving (Narrow)	Medium	Established	63	German	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-[Narrow]Weaver-7	1747	2000s	Weaving (Narrow)	Medium	Established	84	UK	Family (2nd Generation)	Single	NA
E-S-[Narrow]Weaver/Knitter-2	1898	1970s	Weaving (Narrow) & Knitting	Small	Established	20	UK	Family (3rd Generation)	Single	NA
E-M-Weaver/Knitter/Nonwoven-1	1864	1960s	Weaving, Nonwoven, Knitting	Medium	Established	104	UK	Employee Ownership - Private Limited	Single	NA
E-S-Weaver/ Knitter-1	1985	2000s	Knitting & Weaving	Small	Established	12	UK	Private Limited	Single	NA
N-M-Nonwoven-2	1998	1990s	Nonwoven	Medium	NEW	128	UK	Family (2nd Generation)	Single	NA
N-M-Weaver-1	1986	1980s	Weaving	Medium	NEW	100	UK	Private Limited	Multiple	2nd Production Site in UK; 2 Production Sites in USA; 1 Production Site in China
N-M-[Narrow]Weaver-2	1985	1980s	Weaving (Narrow)	Medium	NEW	60	UK	Family (2nd Generation)	Single	NA
N-M-Nonwoven-1	1984	1980s	Nonwoven	Medium	NEW	52	German	Private Limited	Multiple	Subsidary of Large International Corporation
E-M-Knitter-3	1985	2000s	Knitting	Medium	Established	120	German	Group Limited	Multiple	Subsidary of Large International Corporation
E-M-Weaver-2	1811	1950s	Weaving	Medium	Established	110	German	Group Limited	Multiple	Subsidary of Large International Corporation
N-S-Knitter-1	1982	1980s	Knitting	Small	NEW	16	UK	Family (2nd Generation)	Single	NA
E-M-Nonwoven-7	1894	1960s	Nonwoven	Medium	Established	181	UK	Family (3rd Generation)	Multiple	Subsidary of Large International Corporation
E-S-Weaver-3	1985	1990s	Weaving	Small	Established	20	UK	Private Limited	Single	NA
E-M-Weaver-12	1933	1970s	Weaving	Medium	Established	191	UK	Family (2nd Generation)	Multiple	2nd Production Site in USA; 2 Further Production Sites in Europe
E-M-[Narrow]Weaver-1	1860	1970s	Weaving (Narrow)	Medium	Established	60	UK	Family (4th Generation)	Single	NA

Tree	Child	Sub-Child
Strategic Decision Making	**Finance Strategy**	*Financial Diffilculty*
		Financial Growth
		Financial Support
		Investment
		Price
	Location	*International Manufacturing Site*
		International Sales Office
		UK Manufacturing Site
	Product	*Additional Low Value Products*
		Conversion [contract] work
		Customer Services
		End Product
		Intermediate Product
		Non-Technical Textile Products
		Number of Products
		Product Application
		Product Changes
		Technical Textile Elements
Organisational Structure	**Management Team**	*Decision Making*
		Interviewee Background
		Management Style
	Ownership	*British Ownership*
		Change in Ownership
		Employee Ownership
		Family Ownership
		International Ownership
		Shareholders
	Parent Company	*Central Functions*
		Sister Company
	Position in the Supply Chain	*Supply Chain Power Dynamics*
Competition	**Competition Challenges**	
	Competitors	*UK Competitors*
		International Competitors
		Low-Cost Competitors
		Competitor Trade Relationship
	New Competition	
	Price-Based Competition	

Tree	Child	Sub-Child
Competitiveness	**Barriers to Enter TT Market**	
	Customer Flexibility	*Accreditation and Certification*
		Market and Customer Knowledge
		Contracted into Supply Chain
		Customisation
		Repeatability
		Small Batch Production
		Stock Product
		Traceability
	Logistics	
	Market Strategies	*Market Leaders*
		Multiple Markets
		Niche Markets
	Product Strategies	*Added Value*
		Brand
		Bundled Products
		Design
		Increasing Product Portfolio with Customers
		Patents
		Quality
		Unique Product
	Skill & Expertise Capability	
	Small Sized Firm	
	Unique Production Process	*Custom Machinery & Modifications*
Firm Attributes	**Awards**	
	Employees	*Administrative Workforce*
		Contract & Temporary Workforce
		Migrant Worker
		Sales Agent (External)
		Sales Workforce
		Shopfloor Workforce
	Number of Production Sites	
	Profit	
	Turnover	
	Production Process Type	*Weaving*
		Knitting
		Non-Woven

Tree	Child	Sub-Child
Customers and Markets	**Customer Relationships**	*Customer Communication*
	Customers	*Direct Customer*
		Indirect Customer
		Key Customer
		Repeatable Customers
	Market Changes	
	Market Growth	
	Recruiting Customers	*Employee Mobility*
		Exhibit at Techtextil
		Internet
		Market Research
		Marketing
		Reputation
		Website
	New Market Strategy	
	Markets	*Aerospace Markets*
		Automotive Markets
		Export Markets
		Medical Market
		Military Market
		UK Markets
Operations	**Equipment and Machinery**	*Automation*
		Equipment Maintenance & Repair
		New Equipment
	Production Decisions	*Holidays and Closure*
		Output Levels
		Forecasting and Scheduling
		Outsource Products
		Sub-Contract Production
	Production Process	*Additional Processes*
		Distribution
		Dye House
		Finished Assemberly Process
		Inspection Process
	Suppliers	*Access Suppliers*
		Low-Cost Suppliers
		Machine Builders
		Raw Materials
		Supplier Relationship

Tree	Child	Sub-Child
Evolution	**Adaptation of Firm**	*Cost Control*
		Consolidation
		Downsizing
		Entry to TT
		Merges and Acquisitions
		Serendipity
		Vertical Integration
	Challenges	*Commodification of Existing Products*
		Downturn in Market
		Economic Climate
		Equipment Costs
		Foreign Exchange
		Labour Costs
		Limited Suppliers
		Manufacturing Costs
		Manufacturing Time
		Raw Material Costs
		Raw Material Shortages
	Changes in Working Practices	*Employee Empowerment*
		Change in Production Process
		Employee Relations & Teamwork
		Employees Unwilling to Change
		Open Communication Platform
		Staff Incentive
	Future of Firm	*Barriers to Growth*
		Opportunities
		UK Manufacturing Activity
	History of Firm	*Establishment of Firm*
		Survival
		Change in UK Manufacturing Site
		Reason for Location
	Improvements	*Production Efficiency*
Technical Textile Industry	**Developing Countries Textile Industry**	
	European Textile Industry	
	Technical Textile Identity	
	Trade Events	*Techtextil*
	UK Textile Industry	*Government Support*
		Industrial Linkages
		Industry Changes
		Trade Associations
		Reshoring
		Sample Relations

Tree	Child	Sub-Child
Operations	**Equipment and Machinery**	*Automation*
		Equipment Maintenance & Repair
		New Equipment
	Production Decisions	*Holidays and Closure*
		Output Levels
		Forecasting and Scheduling
		Outsource Products
		Sub-Contract Production
	Production Process	*Additional Processes*
		Distribution
		Dye House
		Finished Assemberly Process
		Inspection Process
	Suppliers	*Access Suppliers*
		Low-Cost Suppliers
		Machine Builders
		Raw Materials
		Supplier Relationship
Innovation	**Customer Innovation**	*User Innovation*
		Open Innovation
		Prototyping
		Product Development Process
	Idea and Knowledge Generation	*Employee Input*
		Consultants
		Supply Chain Partners
		Universities
	Innovation Barriers	
	Idea Selection	
	Intellectual Property	*Knowledge Leakage*
		NDA & Condition Agreements
	Process Innovation	
	Product Innovation	*Cross Fertilisation*
		Reverse Engineering
		Testing
	R&D Lab & Team	
	Research Development Projects	*KTP & TSB*

Tree	Child	Sub-Child
Workforce	**Importance of Workforce**	*Key Individual in the Firm*
		Personality and Culture of Firm
	Recruitment	*Kinship Network*
		Industry Poaching
		Local Unskilled Workforce
		Recruit from Closed Textile Firms
		Recruit Non-Local Employees
		University Graduate Level
		Young People
	Redundancies	
	Recruitment Challenges	*Low Wages*
		Perception of UK Textile Industry
	Skill Development of Workforce	*Apprenticeships*
		In-House Training
		Industry Led Training
		Multi-skilled Employees
		Training Challenges
	Skill Shortages	*Ageing Workforce*
		Employee Age Profile
		Response to Skill Shortages
		Succession Management
	Skills	*Employee Attributes*
		Engineering Skills
		Languages
		Problem-Solving Skills
		Technical Department Skills
		Weaving Skills
	Workforce Turnover Levels	*Staff Retention*
Parked Nodes	**Airbus**	
	Carbon Fibre	
	Coating Skills	
	Composites	
	Environmental Issues	
	Invoice Discounting	
	Heritage	
	Responsibility	
	Experience	
	Rolls Royce	
	Scottish Independence	
	Toray	

Tree	Child	Sub-Child
In Vivo (Interviewee Language)	Centre of Excellence	
	Courtaulds	
	Creditability	
	Demographic Cliff	
	Keying In	
	Kit	
	Laurels	
	Lean Manufacturing	
	Miles of Fabric Thumped out	
	Mirroring our Customers	
	Opportunity Pipeline	
	Reinforcing a Manufacturing Process	
	Solution	
	Spreading your Bets	

11 THESIS RELATED PUBLICATIONS

1. Bryson J.R., and **Ronayne M.,** (2014) Manufacturing carpets and technical textiles: routines, resources, capabilities, adaptation, innovation and the evolution of the British textile industry, *Cambridge Journal of Regions, Economy and Society,* 7(3), 471-488

2. **Ronayne M.,** (2015) Manufacturing textile futures: innovation, adaptation and the UK textiles industry, IN Bryson J.R., Clark J., and Vanchan V., (eds) (2015) *Handbook of Manufacturing Industries in the World Economy,* Edward Elgar Publishing, Cheltenham UK.

3. Disney T., Harrowell E., Mulhall R., and **Ronayne M.,** (2013) Doctoral Researcher Skill Development: Learning Through Doing, *Planet*, 27(2), 14-20

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Manufacturing carpets and technical textiles: routines, resources, capabilities, adaptation, innovation and the evolution of the British textile industry

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Since 1966, the UK economy has experienced a continual process of restructuring as manufacturing firms attempted to respond to new forms of competition, alterations in consumer demand and technological developments. Accounts of the British economy since the 1960s highlight deindustrialisation and the transfer of production and employment to newly industrialised regions. The UK is still an important location for manufacturing, but manufacturing has become increasingly mechanised and knowledge-intensive. This article draws upon evolutionary economics to explore the ways in which British manufacturers of carpets and technical textiles have responded to globalisation through the adoption or development of new routines, resources, capabilities, manufacturing strategies and practices.

Keywords: manufacturing, evolutionary economics, routines, capabilities, resources, non-price–based competitiveness
JEL Classifications: L23, O14, O25, R11

Introduction

While 1966 is etched in the UK's historical consciousness because of exploits with a football, it is also significant as the highpoint of manufacturing employment. In 1966, manufacturing accounted for 35% of gross domestic product, employed 8.7 million workers (Select Committee on Trade and Industry, 2002) and was at the centre of the country's post-war boom. From the 1970s, academic accounts of manufacturing, academically and politically, revolved around the ongoing deindustrialisation of the UK (Moretti, 2013), in response to the emergence of international competition and the deterioration in labour relations (Owen, 1999). Accounts of deindustrialisation emphasised the collapse in manufacturing employment rather than continuity of manufacturing production (Cohen and Zysman, 1987; Livesey, 2012; Loch et al., 2007). By 2010, manufacturing in the UK accounted for 11.8% of employment, 14.1% of enterprises, 18.2% of turnover and 19.4% of gross value added (Bryson et al., 2013). During the period of rapid deindustrialisation, British manufacturing firms went through a continual process of adaptation

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to new forms of competition (Boschma and Martin, 2007). Adaptation included consolidation through mergers and acquisitions (M&A), downsizing and offshoring production to low-cost locations (Bryson et al., 2008, 2013).

Accounts of global value chains (Gereffi et al., 2005) highlight the dispersion of production processes across the globe, but have neglected to explore the strategies, alterations or adaptations to routines, practices, processes and products developed by firms located in high-cost production locations (Bryson et al., 2008; Cagliano et al., 2005; Kalafsky, 2007; Mulhall and Bryson, 2013; Sayce et al., 2007). Many of these alterations reflect responses to commoditisation because lower-cost producers undermined the cost basis of manufacturing firms located in high-cost locations (Owen, 1999). In the British textile industry, this led to a period of consolidation during the 1960s through M&As intended to improve performance. This approach unravelled during the 1970s with Britain's entry into the Common Market. British firms were outcompeted by 'Continental fabric suppliers', which had pursued a very different strategy to the British firms as "instead of scale and standardisation, they had put more emphasis on design and technical innovation" (Owen, 1999, 77). The British firms used scale to compete on price, whereas their Continental rivals combined a focus on cost-control with non-price–based forms of competitiveness (design, brand, quality, tradition, heritage, country of origin, customisation, style, fashion, quality of relationships with customers, etc.). The non-price–based elements of a firm's products may be used to try to resist the commoditisation of their products through product differentiation based not on price but on other factors (Baden-Fuller and Haefliger, 2013; Chesbrough and Rosenbloom, 2010; Magretta, 2002; Morris et al., 2005; Teece, 2010).

The non-price–based element may enable a firm to obtain above average profits or rents compared with rivals. The resource-based view (RBV) of the firm notes that firms may use combinations of resources and capabilities that may be difficult to copy or imitate (Penrose, 1959; Teece, 2010). Resources are assets or factors that are owned or controlled by a firm, whereas a capability is the ability of an organisation to select and blend or bundle resources together (Makadok, 2001). Competing on price by stripping out costs is an approach that can be imitated without too much difficulty, but competing on the bases of cost-control combined with other resources, routines and intangibles is an approach, according to Rugman and Verbeke, that blends resources, assets and capabilities as purposive, competitive weapons (Rugman and Verbeke, 2002, 773).

This article identifies and explores the routines, capabilities or practices that manufacturing firms have developed to retain manufacturing production in the UK. The emphasis on firms builds upon the "more general orientation in economic geography from territorial analysis of endowments or institutions to firm analysis of routines and competencies and their embeddedness in the local and global economy" (Frenken and Boschma, 2007, 637). Evolutionary economic geography shifts the focus from the firm as a black box to one in which a firm consists of routines and capabilities that are established over time (Aldrich et al., 2008; Boschma and Frenken, 2011). This is to shift the focus of research to understanding intrafirm and interfirm processes. To Boschma and Frenken ". . . organizations compete on the basis of routines, and competition is driven by Schumpeterian innovation based on new products and technologies requiring new routines, rather than on production costs alone as assumed in neoclassical models" (2006, 278). This is to highlight that a new product and technology may require the establishment of a new routine and that some of these routines reflect a switch from price– to various forms of non-price–based competition. Routines are settled and repeated patterns of behaviour that may both enable and constrain firm behaviour. Routines that constrain may prevent firms from innovating and replacing or modifying

existing routines. Some routines become a form of mindless or passive behaviour in which existing procedures prevent a firm from learning and innovating. An existing routine may mean that employees absorb countless elements from their surroundings, but do not actively process the information—passive absorption replaces active awareness. Nevertheless, an organisation's dynamic capabilities may enable it to learn and innovate and in doing so produce new routines.

The current evolutionary economics literature in economic geography is theoretically sophisticated (Boschma and Martin, 2010) but needs to be supported by detailed firm-level empirical studies. Our concern is with identifying the organisational routines or strategies that manufacturing firms located in the UK have developed to compete with companies located in low-cost locations. We explore two manufacturing sectors: carpets and technical textiles. These sectors were identified because we wanted to compare a mature industry that has experienced intense competition (the British carpet industry) with a new innovative sector (technical textiles). The carpet industry is a mature highly competitive price-based sector, carpet manufacturing in Kidderminster, Worcestershire, and the North West, UK. The British carpet industry has a long and illustrious history, but in recent years, firms have been challenged by alterations in consumer lifestyles, fashions in wood or laminate flooring and also by low-cost imports since 1980s, which adversely affected British firms (Bartlett, 1978; Thompson, 2002). The carpet industry is an excellent example of an industry that continues to alter organisational routines, but has yet to find a 'second wind'. Alterations to routines include replacing labour with machines, shifting production to low-cost locations and consolidation within the industry through M&As.

The technical textile sector is an emergent high-tech sector. The origins of the first industrial revolution are found in revolutionary innovations in two industries that transformed Britain into the 'workshop of the world': cotton and metal (Deane, 1969, 84). The contribution textiles made to Britain's transformation into an industrial economy (Gregory, 1982) suggests that it is important to explore ongoing transformations in this sector. Textile and garment manufacture continue to play an important but declining role in the British economy. Our focus is not on the mature textile industry that produces traditional fabrics, but rather on the production of high-value added textiles. In the UK, textile production is altering as new technological developments have led to the creation of high-value added 'technical textiles', which focus on innovations in the functions performed by textiles. This is a growing emergent sector that provides textile solutions for many other industries, including automotive and aerospace applications, medical technologies (stents), protective clothing (radiation, heat protection), geotextiles, sportswear (sun protection, wicking fabrics), and protective textiles (bulletproof clothing, stab protection). This new technology includes the introduction of technical non-wovens or composites. Developments in technical textiles are revitalising the British textile industry.

In the next section, we explore evolutionary economic geography and specifically the role routines play in firm behaviour. This gives way to a comparison of price– and non-price–based competitive strategies. The article is concerned with practice (Bathelt and Glückler, 2011) and seeks to explore the relevance of theoretical frameworks for understanding sources of competitiveness applicable to specific kinds of industry. To illustrate this approach, we compare the nature of organisational routines and related competitiveness in two contrasting manufacturing sectors—carpets and technical textiles. There has been limited research on these sectors and this is the first article to explore the competitive strategies adopted by these industries in the UK.

Resources, behaviours, routines and capabilities

The economy is in a continual state of change as new firms form, existing firms are acquired

or fail and new technologies emerge that have the potential to destroy existing processes and products (Boschma and Martin, 2007, 537). Firms are in a continual state of transformation as they try to respond to alterations in market conditions, the emergence of new technologies and alterations in consumer demand (Nelson and Winter, 1982). Evolutionary economic geography explicitly adopts a dynamic perspective that complements neoclassical and institutional forms of analysis (Boschma and Martin, 2010). Economic geography must begin to explore processes of firm-level change or adaption and the evolutionary approach "provides a general theory of change while being applicable to specific processes in space and time" (Frenken and Boschma, 2007, 635).

Evolutionary economic geography is part of a more socialised approach to theorising firms that includes three related theoretical approaches that focus on resources, behaviours and routines. First, the RBV on the origins of competitive advantage emerged as one of the standard theories in the field of organisational strategy (Hoopes et al., 2003). The RBV addresses one primary research question: Why does the performance of firms in the same sector vary over time? The RBV argues that a firm's sustainable competitive advantage is based around the possession of a unique bundle of resources and capabilities that provides value as well as barriers to imitation and appropriability (Fahy and Smithee, 1999). A resource is an asset that can be valued and traded, but it does not necessarily have to be tangible. A capability is intangible, not easily observable, cannot be valued and can only change hands when a complete entity is acquired (Makadok, 2001). A firm's marketing, organisational or management capability consists of a bundling together of many different routines that produce distinctive capability. In some accounts, capabilities are considered as 'ownership specific advantages' that provide firms with advantages over potential competitors (Kogut and Zander, 2003). To Teece et al. (1997, 14–5), ". . . the very essence of most capabilities/competencies is that they cannot be readily assembled through markets." To be a source of sustained competitive advantage, a resource or capability must be rare and be isolated from imitation or substitution (Hoopes et al., 2003, 890; Rouse and Daellenbach, 1999).

Second, a behavioural approach to theorising firms was most fully developed in the work of Cyert and March (1963) who conceptualised the firm as a site of decision-making in response to conflict, uncertainty, problem-solving, learning and adaption; adaption or change may occur when goals related to production, sales, market share and profits are not met. In this account, firms are situated within networks of transactions that include relationships with managers, workers, stockholders, suppliers and customers. Third, Nelson and Winter (1982) added an evolutionary perspective to the behavioural theory of the firm. The evolutionary approach starts with the premise that firms rely on organisational routines that shape production and decision-making processes (Frenken and Boschma, 2007; Nelson and Winter, 1982). Routines are predictable and based on experience and develop over time and may, to a significant extent, be idiosyncratic. Firms that evolve and change build on their prior resources, capabilities and routines. In extreme cases, this may involve replacing existing routines, but existing routines often limit the flexibility of firms and reduce their ability to respond to external pressure. External pressure may come from not only the introduction of new products in to the market but also the commoditisation of existing products through price-based competitiveness. A firm may be unable to respond to these external pressures either because they have limited understanding of market processes, limited resources and capacity or existing routines prevent change from occurring (Slater and Tonkiss, 2001).

Firms are involved in three types of decisions: strategic, administrative and operational (Ansoff, 1968). Strategic decisions are long-run

planning decisions involving the relationship between a firm and its environment and include product decisions, factor inputs and their location and finance strategy. Administrative decisions concern the establishment of a firm, governance and organisational structures. Operational decisions involve repetitive short-run routine decisions regarding price, output levels, control of operations and the production process. These different types of decisions include specific routines that have developed over time through experiential learning. Behavioural and microeconomic approaches to firms have tended to focus on operating decisions (Cyert and March, 1963; Taylor, 2006). To Ansoff (1968), the core decision for a firm revolves around the selection of the product–market portfolio. This is a critical aspect of competitiveness for firms located in high-cost locations.

Traditional economic theory highlights price, product and selling effort as the key determinants of competition and the growth of firms (Koutsoyiannis, 1992, 2). A product contains many different dimensions, including technical characteristics, quality standards, design, style, colour, packaging and product-related services (Bryson, 2009; Bryson et al., 2004). Much of the focus of economic geography has been on price and the geographical organisation of production to reduce production costs (Christopherson and Clark, 2009; Lane and Probert, 2004; Tokatli and Kizilgun, 2010). Yet, "non-price competition (product style, and advertising selling strategy) has become more important than price competition [but] . . . non-price competition is rarely mentioned" (Koutsoyiannis, 1992, xix). Competition founded on price is a core driver behind the emergence of global commodity chains. Firms that compete only on price can be copied by competitors and often undercut, but imitating product design, branding, product-related services or a company's heritage is difficult and takes time (Bevia et al., 1999; Bryson and Rusten, 2011; Rusten and Bryson, 2010). In economics, non-price–based competitiveness has focused on advertising and sales strategies and has neglected many other assets and strategies that firms can deploy to provide them with forms of non-price–based competitiveness or product differentiation that is not based only on price. The RBV plays a central role in understanding non-price–based competitiveness, given the emphasis that is placed on intangible and difficult to imitate capabilities (Hoopes et al., 2003; Makadok, 2001; Rugman and Verbeke, 2002; Taylor, 2006) to prevent copying (Shenkar, 2010). Non-price–based strategies include a focus on continuous innovation, small batch production, niche markets, quality, speed based on closeness to market, service, customisation or personalisation, design, fashion and/or style, place-based associations (Rusten et al., 2007), branding and heritage (Bryson et al., 2008; Bryson and Rusten, 2011). These strategies combine advantages related to geography and product to create competitiveness. They highlight the importance of understanding the relationship between strategic, operational and product decisions, and also the role path dependency, based on product brand or heritage, plays in firm strategies. These strategies, combined with appropriate cost-control, enable manufacturing to continue in high-cost locations.

The emphasis in evolutionary economic geography is to "open the black box of organizations and to view organizations as competing on the basis of their routines that are built up over time" (Boschma and Frenken, 2006, 277). In this perspective, organisations' decision-making is not based on utility maximisation, but on bounded rationality and routine behaviour. Routines may prevent change and lead to firm failure through path dependency (Martin and Sunley, 2006). The importance of firm routines that reflect behaviours as well as resources and capabilities is a critical element of understanding the ways in which firms grow and compete. Central to this approach is a concern with the evolutionary principles of variety, selection and

retention. Firms alter their routines through trial and error, incremental changes, learning by networking, copying and imitation, recruiting employees from competitors and through M&As (Boschma and Frenken, 2006; Boschma and Martin, 2010). Routines include both the tangible resources and intangible capabilities identified by the RBV of the firm. This implies that routines includes not only management or organisational styles and cultures (Marshall [1921] 1961, 138–9), production processes, mechanisms of cost-control, but also more intangible elements related to brands, design, fashion, style, heritage and even place-based associations (Bryson and Rusten, 2011). In this article, we are interested in identifying and understanding the different routines that firms manufacturing carpets and technical textiles in the UK have developed to survive in a relatively high-cost production location. Our theoretical approach combines the RBV, behavioural and evolutionary approaches to understanding resources, capabilities and behaviours as routines. Routines may apply to all products in a firm or may be product specific. Nevertheless, it is important to identify and understand specific routines that have developed within individual firms and across sectors. It is to this task that we now turn our attention.

The British textile industry—research design and methodology

The British Textile industry has experienced a continuous decline since 1913 (Miller, 1962), and textiles was one of the first industries to develop an international dimension. Our research design is a comparative firm-level analysis of two related industrial sectors: technical textiles and the carpet industry. The methodology is based on a desk-based analysis of these two sectors that produced a comprehensive list of existing companies. This list was compiled from FAME, Yell-Com business directory, trade association membership lists, online directories and social media, including Twitter, Linkedin and Facebook. A sample of firms from each sector was selected and firms contacted with a request for face-to-face interviews. Respondents were managing directors, operation managers, sales directors and technical directors. In all, 25 carpet manufacturing companies were identified from the directories. All were contacted and 12 firms agreed to be interviewed. Semistructured interviews were undertaken between March and June 2011. Seventy-seven technical textile manufacturers were identified by the desk-based analysis and 39 were interviewed between October 2012 and September 2013. The sample is representative of the firms operating in each sector; no difference has been identified between the firms that were interviewed and those that declined to participate. Accessing these firms was difficult because of concerns over commercial sensitivity related to intellectual property rights. The interviews were transcribed and, to maintain anonymity, each company has been assigned a code. Our analysis can be generalised across the British carpet and textile industries and can inform the analysis of other similar sectors. In the following sections, we identify the firm-level routines, behaviours and capabilities developed by British firms manufacturing carpets and technical textiles.

British carpet manufacturers: routines, adaptation and new technology

The origins of the British carpet industry can be traced back to the persecution of Protestant Huguenots by King Louis XIV of France in 1685. Many of the Huguenots fled France and settled in Holland, Germany, England and Ireland where they played an important role in developing the cloth industry (Wells, 1972). From 1736, Kidderminster, West Midlands, UK, developed as an important centre for the production of carpets (Brinton, 1919, 5; Thompson, 2002). By 1913, there were 45 British carpet manufacturers: 11 located in Scotland, 9 in the

North of England, 18 in Kidderminster and 7 elsewhere (Brinton, 1919, 104).

Since the 1960s, the industry represents a sector that has declined despite access to local raw materials and a long history of carpet manufacturing. By 2011, 25 firms continued to manufacture carpet in the UK (Figure 1). Most firms only had production facilities in the UK

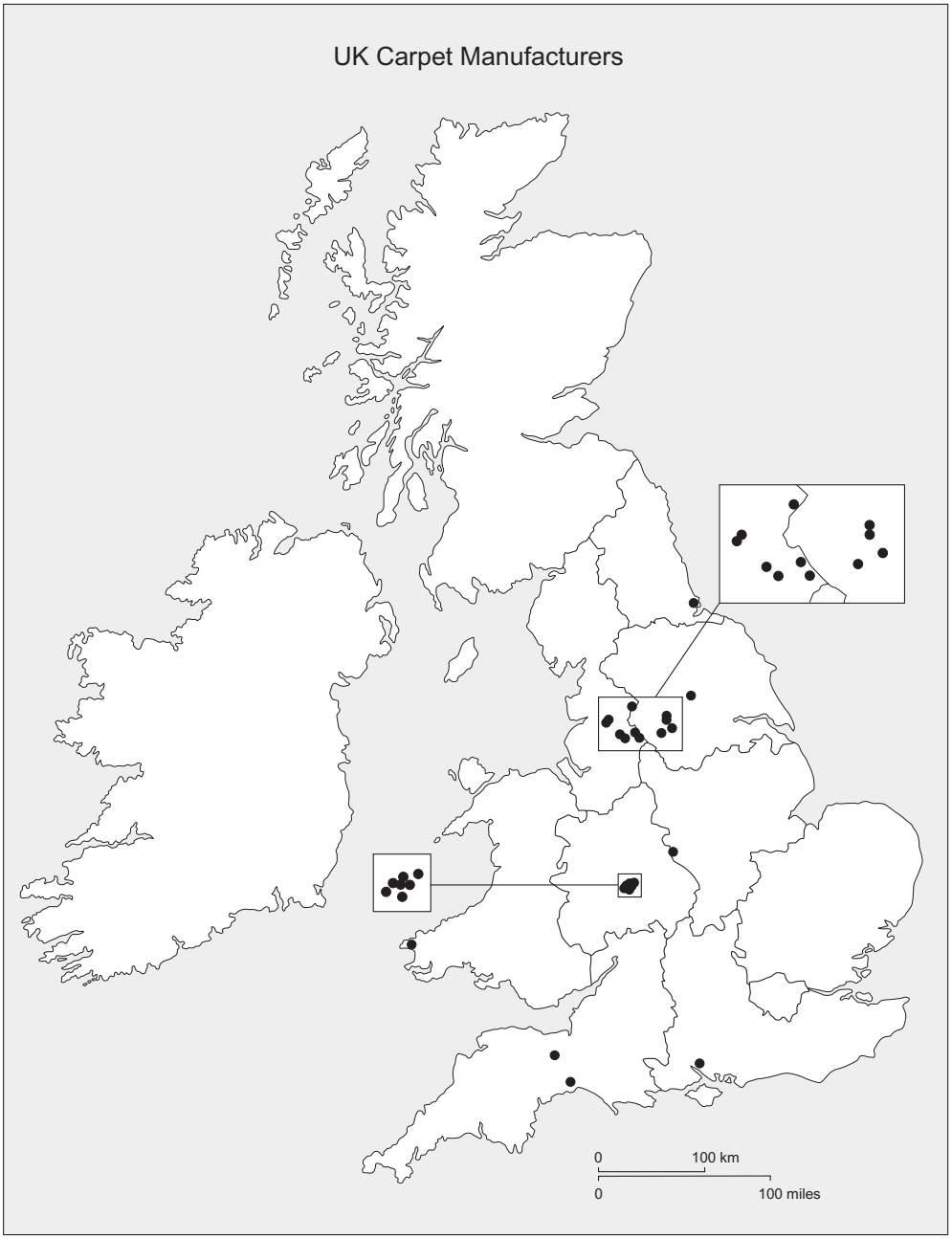


Figure 1. *The Location of British Carpet Manufacturers, 2012.*

and were only involved in global production chains through the sourcing of wool from New Zealand. The decline in British carpet manufacturing is partly driven by alterations in fashions, developments in carpets made from artificial fibres, shifts in consumer demand from patterned to plain carpets and the import of cheap carpet into the UK manufactured by Belgium, Indian or Chinese manufacturers. The British carpet firms specialise in patterned woven rather than plain tufted carpets (Thompson, 2002). Woven carpets are produced on looms which bind the pile tufts in position with the backing yarns. A tufting machine uses a bank of needles which spans the width of the carpet. The needles are threaded with a continuous supply of yarn. Tufted carpet is much faster and cheaper to manufacture; the average carpet loom can produce between 15 and 20 tufts per minute, but a tufting machine can produce over a 1000 tufts. In 2002, the cost of manufacturing tufted carpet was £0.89 per square yard compared with £1.64 for woven carpet (Thompson, 2002, 124). Initially, British carpet firms faced competition from Belgium firms using the latest tufting machines so that carpet production "looked like fax coming out of a fax machine" (Interview, Firm A.5). The UK carpet industry began to experience commoditisation with the introduction of tufted carpets machines in 1952; by 2009, tufted carpet accounted for 73% of all carpet manufactured in the UK (CFJ, 2009). Four of the interviewed firms had switched from the production of woven to tufted carpet because the market for woven carpet had become too competitive. Three firms produce both tufted and woven carpet and six firms continued to produce woven carpet. These firms have focused on the quality end of the market by developing a blend of 80% wool and 20% nylon carpet and increased the variety of designs and colours. A tufted carpet machine is able to produce 220–240 designs and the machine primarily produces geometric designs. Woven machines have no limitations in terms of colours and shapes. The UK still manufactures 38% of the carpet sold in the UK and supplies carpet for residential as well as commercial markets for leisure and business industries (Sayce et al., 2007). The surviving British carpet firms have applied organisational routines intended to reduce production costs based on the adoption of new machines with a shift from woven to tufted carpet combined with non-price–based competitiveness based on design and colour. This has included ongoing consolidation and cost-control.

Consolidation and cost-control

The demand for carpet is closely linked to the construction industry. There is an important lag time between an upturn in construction and the housing industry and an upturn in the carpet industry. Carpets are a discretionary rather than essential purchase. The UK has many famous carpet brands, including brands that describe particular types of carpet—Axminster and Wilton. There is a long history of M&As within the industry and of carpet firms entering administration during recessions. The carpet industry is mature and given this the firms are 'precarious'; consolidation as an organisational strategy continues to occur to increase efficiency and competitiveness and in response to economic downturns. Precarious firms are in a continual state of becoming, adaptation or evolution. Such firms may alter routines to try to adapt to uncertainty and intense competition, but may also engage in M&A activity that shuffles assets between firms. In February 2013, Axminster carpets went into administration and 300 employees were made redundant. The firm's assets were acquired by a Somerset businessman who rehired 100 employees. By September 2013, the firm had recruited another 50 staff as it had won high-profile contracts, including an order to provide carpet for a committee room in the US House of Representatives. Five of the firms interviewed had acquired failing carpet firms since 2002. One firm acquired two weaving firms to increase production capability.

Four firms retained the brands that they had acquired. M&As led to the retention of established brands by the acquiring firm, but the closure of manufacturing production. In 1992, the Headlam Group, Birmingham (UK), was formed through the acquisition of failing carpet firms located across Europe. The firm owns over 40 brands that are distributed through a shared warehouse and distribution infrastructure, but manufacturing is outsourced. Competition in the industry continues to intensify as wholesalers acquire brands, but close factories and outsource manufacturing to low-cost producers located abroad.

Labour is the highest proportion of production costs for woven carpet manufacturers; weaving requires craft skills (Sayce et al., 2007). Price-based competition has become a threat for these firms as lower-cost locations are beginning to weave high-value added carpet at lower production costs. This means that carpet producers located in lower-cost locations are beginning to combine price-based competitiveness with the non-price–based organisational routines adopted by British carpet manufacturers. One firm noted that:

> It's about £23 a square metre to make [Axminster carpets] here [UK], you pay that against £13 in India, that's £10 difference… the sales guys struggle to sell a high-cost product, so it's had a devastating effect here, we've had to go on short time, we've had extended shutdowns, we've had to take shifts off here and down size the plant (Interview, Firm A.11).

All firms interviewed stated it was critical to control and reduce production costs to be able to continue to manufacture in the UK. One firm noted that they were:

> driving down costs, basically it's the only way you can do it, you've got to keep taking costs out of the carpet. I mean we've taken 20% out of our fixed overheads on this site in 2 years…, that's the only way that we can compete against low-cost manufacturers (Interview, Firm A.11).

Most firms noted that the penalty of failing to control costs "is the ultimate failure of losing your business" (Interview, Firm A.7). One response to cost-control has been to transform the production of carpet for the residential market into 'just-in-time' manufacturing.

Adaption and non-cost–based competitiveness

Carpets for the residential market are supplied directly by the manufacturers to independent retailers. Retailers have altered this relationship and forced manufacturers to reduce the time between order and supply. The British companies are now able to manufacture and deliver an order within 48 hours. Eight of the firms have their own delivery vans, and one firm employed nearly 70 in production and 70 people in distribution. Speed of response and the ability to produce to demand have become a central element of British carpet firms' organisational routines and are a key source of competitiveness. This highlights the important contribution local logistics makes to production networks and to a firm's capabilities. The British carpet manufacturer's production network is predominantly local with global production networks used by large retailers and wholesalers to source low-cost carpet. Cheap artificial fibre carpet has become fashionable, as the home furnishing industry has been transformed into a fashion-driven industry over the last two decades (Leslie and Reimer, 2003). Individual rooms are redecorated more regularly to follow fashion. Residential consumers are trading down from wool-rich products to artificial fibre; consumers can afford to change cheaper carpets more frequently to match alterations in fashion.

The production of carpet for the commercial market is undertaken via a process of co-production between the manufacturer and the

customer. The carpet is designed and made to order and it is:

> . . . almost like boutique manufacturing, which is probably why it has survived in the UK, everything is made to order, most of what we make is especially designed for the customer and the essence of this business is making our customers' premises successful, so when you are the Savoy hotel you want a muted classy feel and when you are a bowling alley you want a loud brash exciting feel (Interview, Firm A.6).

All firms interviewed compete on delivery times, nearness to market and flexible production systems rather than just on price. The carpet firms have developed more flexible routines that enable the production of customised carpet as well as carpet that is made just-in-time and delivered just-in-time. Low-cost foreign carpet manufacturers do not have the ability to offer this same level of responsiveness:

> The other thing why we can resist low-cost competition from the Far East and south Asia is … because it's big heavy stuff and the time it takes to get here adds as well, so very often … they'll say here's the order on Monday, we want first deliveries in two weeks time, you can't do that because it's 3 weeks on the sea [from China] (Interview, Firm A.6).

British firms are exporting carpet by exploiting the 'Made in Britain' association, heritage brands, quality, design and technology.

In 2010, Brintons, a manufacturer of woven carpets established in Kidderminster in 1783, wove and supplied the world's largest single commercial carpet for the Terminal 3 building, Gandhi International Airport, Delhi. This involved the production of 175,000 square metres of carpet that took 3 months to weave using 20 looms (The Shuttle, 2010). Brintons was rescued from the brink of insolvency in 2011 by *The Carlyle Group*, an American-based global private equity firm. The company had been owned by over 100 members of the Briton family who were unable to reach a consensus regarding the company's strategic direction. Brintons had developed into a global carpet brand through M&As and the establishment of design studies in London, Kidderminster and Pune (India) and manufacturing facilities in the UK, Portugal and India. Before the acquisition, the Brinton family were building a factory in China and had planned to close the firm's UK production operations. Carlyle closed the Chinese factory to exploit the 'Made in Britain' label that was an important part of the firm's non-price–based attraction for American and Asian customers. In April 2013, Brintons announced that it was making a £3m investment in new equipment it had developed to make carpet for major buildings and cruise liners. The new proprietary looms will weave high-definition carpets from photographs for the international market and can include 32 colours instead of eight. This innovation reflects a technological solution to obtain product-based distinctiveness that combines firm organisational routines related to the control of production costs with non-price–based capabilities linked to design, technical innovation and customisation.

The companies have been investing in the promotion of their brands and by developing their online presence. Many have tried to have their products featured in magazines targeting private consumers. Potential consumers then explore a firm's website where they can request free samples that will be delivered within 48 hours. Companies have focused on design as a key product differentiator. By being design-led, they can produce products that will not be available from the low-cost volume manufacturers. This includes, for example, 'technical' carpet developed for care homes, retirement villages, clinics and private healthcare practices using antimicrobial technology combined with an impervious back to cope with spillages. This product-based approach is part of

an internationalisation or export strategy that is based on investing in distribution channels targeting core European markets. The firms have had to "think more European, international in our look of colours" (Interview, Firm A.10). Some firms have also introduced services including design services, project management, carpet fitting, aftercare advice, cleaning and insurance.

The British carpet industry is an excellent example of a sector that consists of 'precarious firms' that have to respond to continual market uncertainty, turbulence and also alterations in fashion. The surviving British carpet firms continue to respond to low-cost volume competitors located in Europe and Asia by combining resources, routines and capabilities that are about cost-control with non-price–based sources of competitiveness (design, speed of delivery, closeness to market). The firms have been transformed into producers of made-to-order carpets that can be co-created or co-designed for commercial clients. Continual product development and innovations in supporting services, including logistics, are critical for the continual survival and growth of the carpet firms. Surviving firms have built upon established assets and resources, including their accumulated design libraries, brands and heritage. These assets have been combined with new technologies and innovations in logistics. The British carpet market is extremely competitive and price sensitive. To survive, British carpet firms must continue to alter existing routines and develop new routines through innovation and exploiting the advantages of speed of delivery and quality of design and product. Future growth may occur based on exports and the supply of customised commercial carpets. To survive and grow, the British carpet manufacturers must continue to strip out costs through technical and process innovations. An emphasis only on alterations in routines intended to strip out costs will not protect the British firms from overseas competition; cost-control must be combined with routines and resources intended to create product differentiation. This highlights the importance of blending evolutionary economic geography with the RBV of the firm to understand routines and resources that are difficult to imitate.

Technical textiles: new technology, certification and branding

The technical textile sector is a complex emergent and heterogeneous industry. It is debatable whether this is a sector given the variety of products that range from non-woven technical textiles made of composites to traditional woven fabrics that have been coated to provide additional functionality. Unlike the carpet industry, this sector has yet to be commoditised, and firms are competing on the basis of continual innovation and the introduction of new products. Unlike the carpet industry, most of the firms supply products that are intermediate inputs into other products, for example, wind turbines and aeroplane ejector seats. The geography of the industry reflects the historic evolution of the English textile industry (Gregory, 1982) with a focus in Lancashire, Yorkshire, the East Midlands and Scotland (Figure 2).

Technical textiles are created by combining weaving and chemistry, to produce new-coated products, by spinning yarns that blend different materials or by the creation of non-woven textiles based on composites. The emergence of technical textiles reflects a dramatic reallocation of assets and resources held by established traditional textile firms and the development and application of new technology. Research and development was undertaken in-house by all firms. Some companies had sponsored PhD students at local universities, but this was unusual.

The technical textiles sector is an emergent industry founded partly by conventional textile firms developing new products that blend existing assets with new technologies, but there are complications. Twenty-nine of the 39 firms that were interviewed had shifted from the

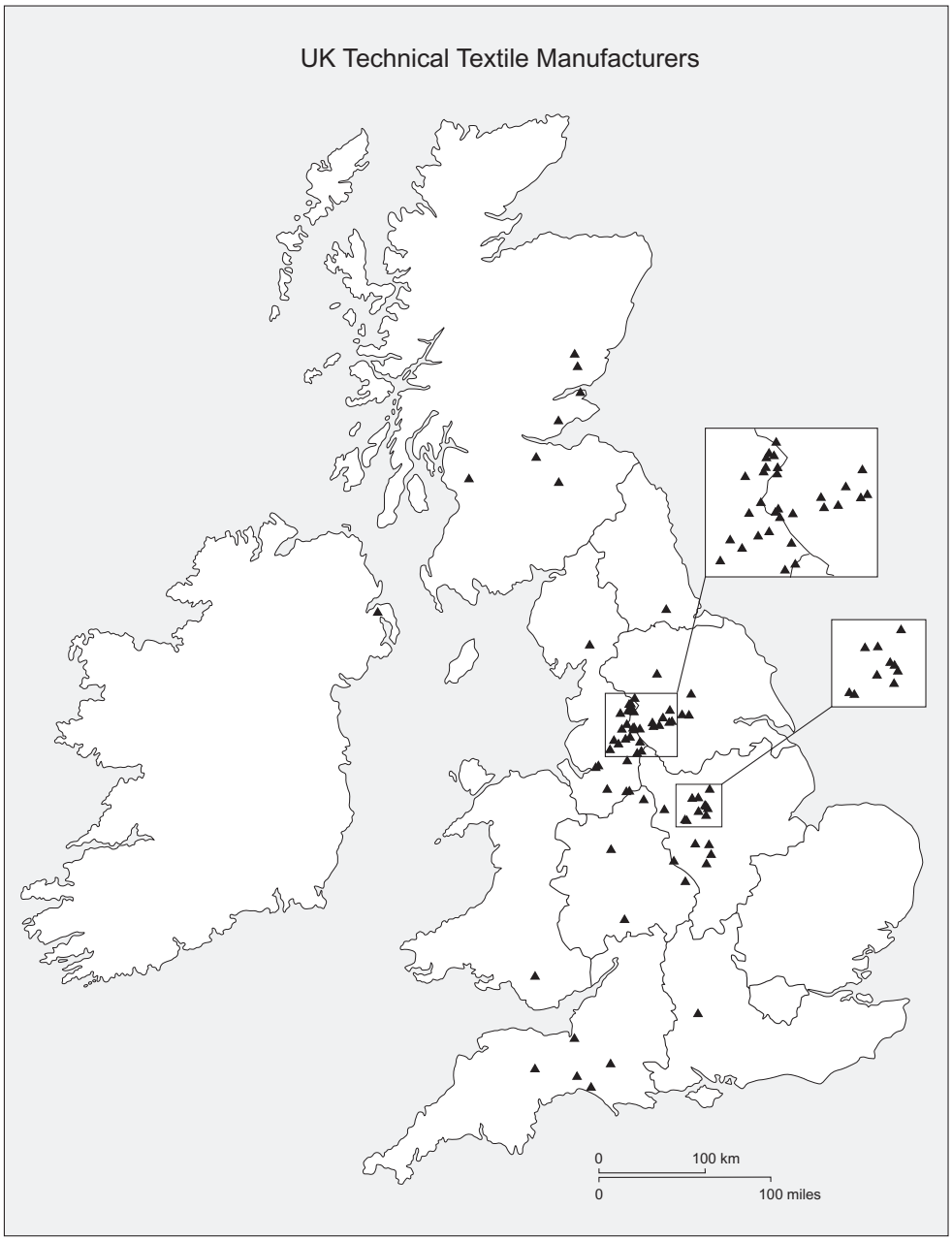


Figure 2. *The Location of Firms Involved in the Production of Technical Textiles, 2013.*

production of textiles to technical textiles; 16 had been established in the 19th century. Some of the technical textile firms had been created through non-textile firms, acquiring the assets of failed textile firms. Eight of the technical textile firms had complex origins. Two had spun out from research departments of Courtaulds, a large British manufacturer of artificial fibres,

chemicals and textiles, and two companies had been established by purchasing failing suppliers. A paper manufacturer and a manufacturer of textile machines evolved into manufacturers of technical textiles. Managing directors, who had previously worked for large textile companies, were responsible for establishing two of the companies.

Three main reasons explain the shift from textiles to the production of technical textiles. First, price-based competition from producers located in Asia undermined the competitiveness of many British textile firms producing non-technical textiles. The British firms were unable to compete on price, and many firms closed or transferred production overseas (Owen, 1999). Second, the introduction of new technology, including machinery, played an important role in the formation of this sector. Third, consumer-led changes and the development of new products have created a demand for different types of textiles. Technical textile companies compete on the basis of innovation, relationships with clients, equipment, certification and vertical integration. Firms compete by combining or blending capabilities, resources and routines together to compete using price– and non-price–based sources of competitiveness.

Relationships, regional assets and non-price–based competitiveness

Technical textile companies compete using organisational capabilities and resources that include non-price–based elements, including focusing on niche markets, quality, service and responsiveness. Speed of delivery is critical with firms being able to provide products within 48 hours. Low-cost producers are resourced to manufacture high volumes and set high minimum orders. The British technical textile companies either set very low or no minimum order thresholds. These orders cannot be processed by firms located in Asia and provide British firms with a continuous stream of repeat orders and a form of inimitability. Another key strategy is based on the establishment of close trust-based personal relationships with client companies. Companies, especially those producing narrow fabrics are operating in a very competitive market segment. There are many firms producing similar products; all firms interviewed noted that product orders are determined by personality and the quality of the long-term relationship that they have with clients. Trust and the quality of the relationship between the firms' sales teams and customers play an important role in the organisational capabilities developed by British technical textile firms. Nevertheless, this advantage is destroyed when key individuals leave the firm or there is a change in the buyer's employees.

Proximity to clients is a critical asset that was identified by 33 (85%) of the firms. This ensures speed of response and the ability to meet to discuss potential innovations and difficulties. Technical textile firms provide intermediate inputs that are transformed into complete products by their customers. Producing intermediate inputs means that the firms must also understand the requirements of their customers' markets. Many different types of products are produced for many different markets; one technical textile firm produced products for 12 different markets. This highlights the complexity and variety of the organisational routines required to provide products for many different market segments. The relationship with clients is so critical that some firms recruit employees who used to work for end users. This enabled the technical textile firms to understand their clients and to build upon established relationships. Technical textile firms have relocated to be close to important customers; two firms had established branches in the US and China to continue to meet the needs of customers who had relocated.

Competitiveness strategies—equipment, certification and vertical integration

Three primary competitiveness strategies developed by technical textile manufacturers

based in Britain were identified during the interviews. These highlight the ability of firms to compete from a relatively high-cost production location by combining capabilities, resources and routines.

First, routines and resources are related to the technical abilities of a firm and these reflect an attempt to use technical resources to create inimitability. It was noteworthy that many of the firms would not permit access to their shop floors. Fifty-four per cent of the firms were using similar production equipment but with special proprietary additions. These additions and modifications were considered to be commercially confidential. These bespoke additions were either developed in consultation with machinery manufacturers or modified by a firm's own engineers. One firm purchased machines but did not want the manufacturer to ". . . know what we were doing, so you might buy the kit and then make modifications" (Interview, Firm 66). Another firm noted that all the R&D machinery modifications were "all done in-house, you keep something like that to yourself otherwise everybody would be buying it [from the machinery manufacturers]" (Interview, Firm 68). Alterations made by machinery manufacturers were covered by non-disclosure clauses to prevent proprietary innovations from being acquired by competitors.

Second, the British firms had developed product capabilities based around certification. Thus, 59% of the firms produced products that were independently certified to meet industry regulations. These included aerospace, military, defence, safety harnesses and medical products. Accreditation of a company's fabric as an intermediate input into a certified final product makes it expensive for the client to identify a cheaper substitute. Any substitution would mean that the product and its production process would have to be reaccredited. The production of certified products locks the technical textile firms into supply chains providing them with market security. For one firm, 50% of their products are certified and thus ". . . the activity is stable and you know as a result it gives us a good base to make sure that the next business activity can be established and pushed forward so you know we're not looking over a cliff" (Interview, Firm 97). This type of lock-in provided some firms with a 30- to 40-year locked-in relationship with a customer.

Third, the British manufacturers of technical textiles had developed products that emphasised the importance of developing and projecting a distinctive brand identity. The British textile industry was dominated by large companies that produced products for large retail chains. These larger firms outsourced key processes to British anonymous contract manufacturers. The anonymous contract manufacturers were in a dependant position; retail clients were able to force them to reduce their profit margins by playing one contract manufacturer off another. These larger textile firms either failed or switched production to low-cost locations (Owen, 1999, 78–82). Technical textile firms developed through vertical integration (36% of firms) or by creating their own branded products (26% of firms); anonymous subcontractors were transformed into manufacturers of branded products. Firms acquired subcontractors as the market declined, to control the production process or to offer customers a one-stop-shop textile service. Technical textile companies developed their own brands either by creating a new product and brand or by acquiring one of their customers. An 'own brand' is a resource that guarantees that some of the firm's textile production is included in to the company's branded products.

These three approaches combine or blend resources, capabilities and routines and reflect different approaches to creating competitiveness. New technical textiles produced using proprietary manufacturing technology might be incorporated in to a customer's certified products. This is a technical product-centred solution to enhance the competitiveness of a technical textile firm. The acquisition of firms and assets is opportunistic behaviour that

is partly about acquiring depreciated assets and resources cheaply. The emergence of new branded products and companies transforms anonymous suppliers or firms that had been captured by larger firms into relational or even integrated firms (Gereffi et al., 2005); relational firms co-create products for clients and integrated firms produce completed products. The transformation of smaller textile firms into technical textile firms reflects a shift in their position within commodity chains. Firms that had become subservient or dependent on original equipment manufacturers have managed to reposition themselves through the development of new products that have yet to be transformed into price-based commodities. Certification and proprietary knowledge are been used to prevent commoditisation and to ensure that technical textile firms compete by providing solutions that are difficult to imitate. These solutions combine technology, certification and co-innovation that is based on established relationships.

Conclusion

Academic discussions of manufacturing have been too dominated by accounts of the new international division of labour or the shift of production from high- to low-cost locations. This has meant that social scientists have overlooked processes of continual innovation and adaptation that have transformed manufacturing firms based in high-cost production locations.

In this article, we have developed a practice firm–centred approach to understanding sources of competitiveness in two textile industries informed by three related theoretical perspectives: RBV, behavioural approaches to the firm and evolutionary economic geography. Blending these approaches highlights the importance of understanding firm behaviour through the development and modification of organisational routines that combine resources into distinctive capabilities. Carpet manufacturing still plays an important role in the Kidderminster economy, but it is a precarious role involving processes of continual restructuring because existing organisational routines are evaluated to strip out costs. The carpet firms are precarious because survival has involved an ongoing process of consolidation. Assets are been shuffled between firms to develop economies of scale. The precariousness of the carpet firms reflects the operation of a precarious industry which is closely aligned not only to the housing market but also to lifestyle alterations. The surviving carpet firms have transformed themselves into manufacturers of made-to-order carpets that can be co-created or co-designed with clients. The firms combine a focus on cost-control and price-based competitiveness with deploying capabilities that blend assets and resources to provide sources of non-price–based competiveness, and these assets include branding, heritage, accumulated design libraries, logistics, speed of response, quality and place-based associations. The British carpet industry is segmented into two distinctive markets—home and commercial—and these two markets provide the British firms with an ability to transfer machines and labour between segments.

The technical textile industry is emerging from the remnants of Britain's textile industry that played an important role in the first industrial revolution. This new industry is an excellent example of an emergent industry based on existing firm and regional assets that have been used to create new products. The technical textile industry is a new manufacturing activity that is exploiting as well as creating new markets. These 'new' firms respond to client needs through the development of co-created textile solutions, but they are also developing new technical textiles that are creating new product categories. The technical textile sector is extremely complex because it provides solutions for many different industries. This heterogeneity provides resilience as firms are locked into many different value chains. The

technical textile industry reflects developments in machinery combined with innovations in chemistry. This combination has led to the establishment of a group of firms that are developing organisational routines, resources and capabilities based on blending chemistry with new forms of weaving to create new products. These are high value textiles and many require certification before they are incorporated into final products. Certification combined with other forms of non-price–based competitiveness highlights that the technical textile firms are trying to prevent their products from been transformed into price-based commodities.

This article has identified organisational capabilities, routines, resources and practices that manufacturing firms located in high-cost locations have developed to compete with lower-cost producers. In detail, many of these organisational routines are idiosyncratic, but a set of more generic routines can be identified through theoretically informed empirical research. It must be noted that routines can constrain innovation because they represent established and sometime mindless practice. Successful firms are able to replace or modify existing routines or to develop more flexible routines. To alter routines, firms must be receptive to new ideas and practices. It may be that dynamic capabilities based on organisational learning are the ultimate cause of firm survival or adaption. Successful firms not only combine capabilities, resources and routines, but also challenge their existing routines.

Economic geographers need to identify and explore the different ways in which firms compete by developing organisational strategies that blend firm- and regional-based resources with routines that emphasise cost-control with product differentiation. The focus on labour costs, jobs and global commodity chains that has dominated political and academic discussions of manufacturing must be supplemented by detailed research on organisational routines, capabilities and practices developed by firms located in high-cost production locations. The existing emphasis placed in economic geography on global value chains (Dicken et al., 2001; Gereffi et al., 2005), outsourcing and offshoring has led to a relative neglect of the organisational routines, capabilities and practices developed by manufacturing firms. Economic geography needs to identify the different organisational routines developed by firms in different sectors and located in different countries. Further research is urgently required to understand the time–space distribution of organisational routines; firm-based capabilities and routines vary over time and between places. Nevertheless, a focus on organisational routines must be combined with an understanding of resources and capabilities. This is to argue that economic geography must combine the RBV of the firm with evolutionary and behavioural approaches to understanding firm behaviour. This theoretical blend offers interesting possibilities for understanding the evolving economic geographies of manufacturing.

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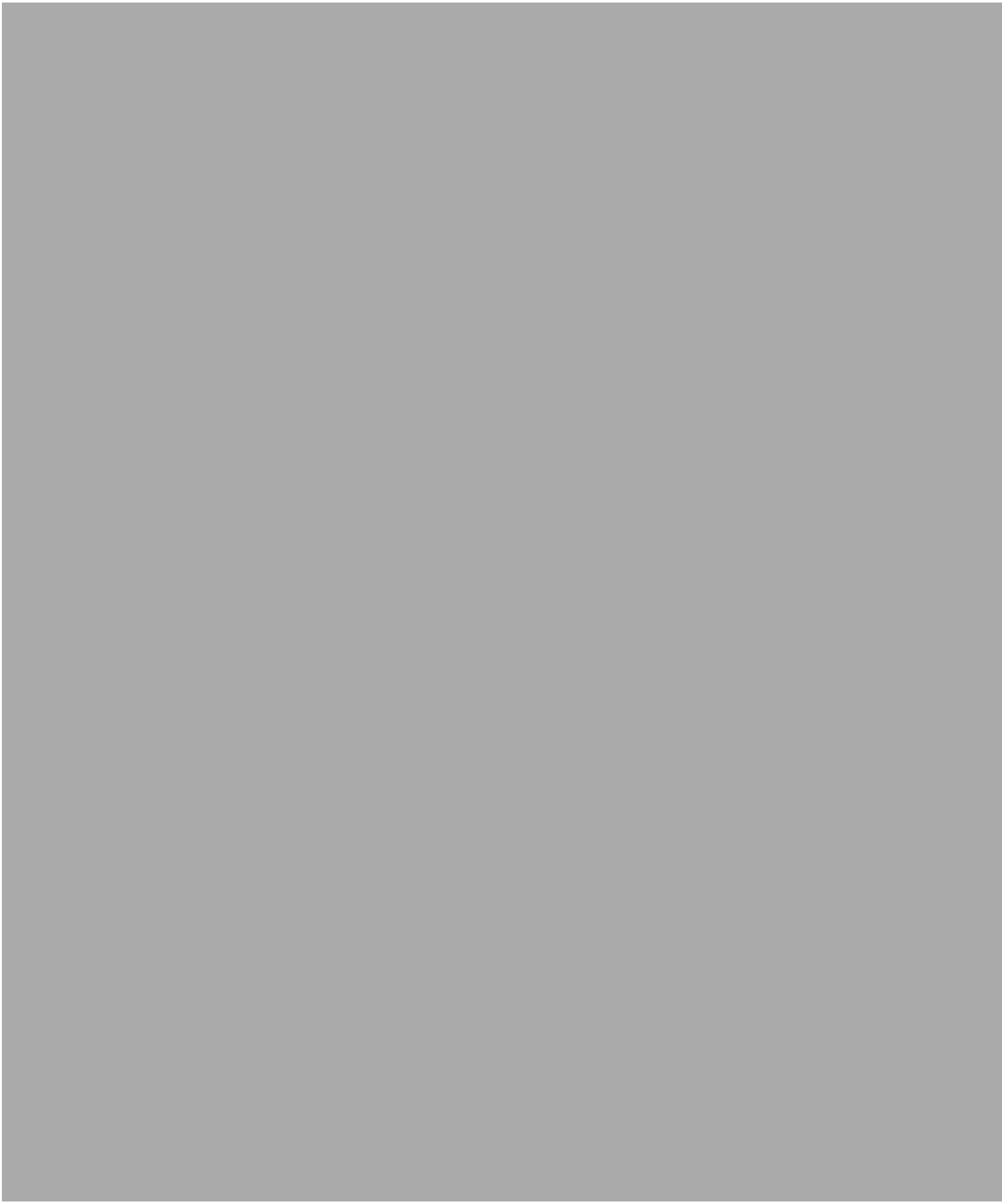
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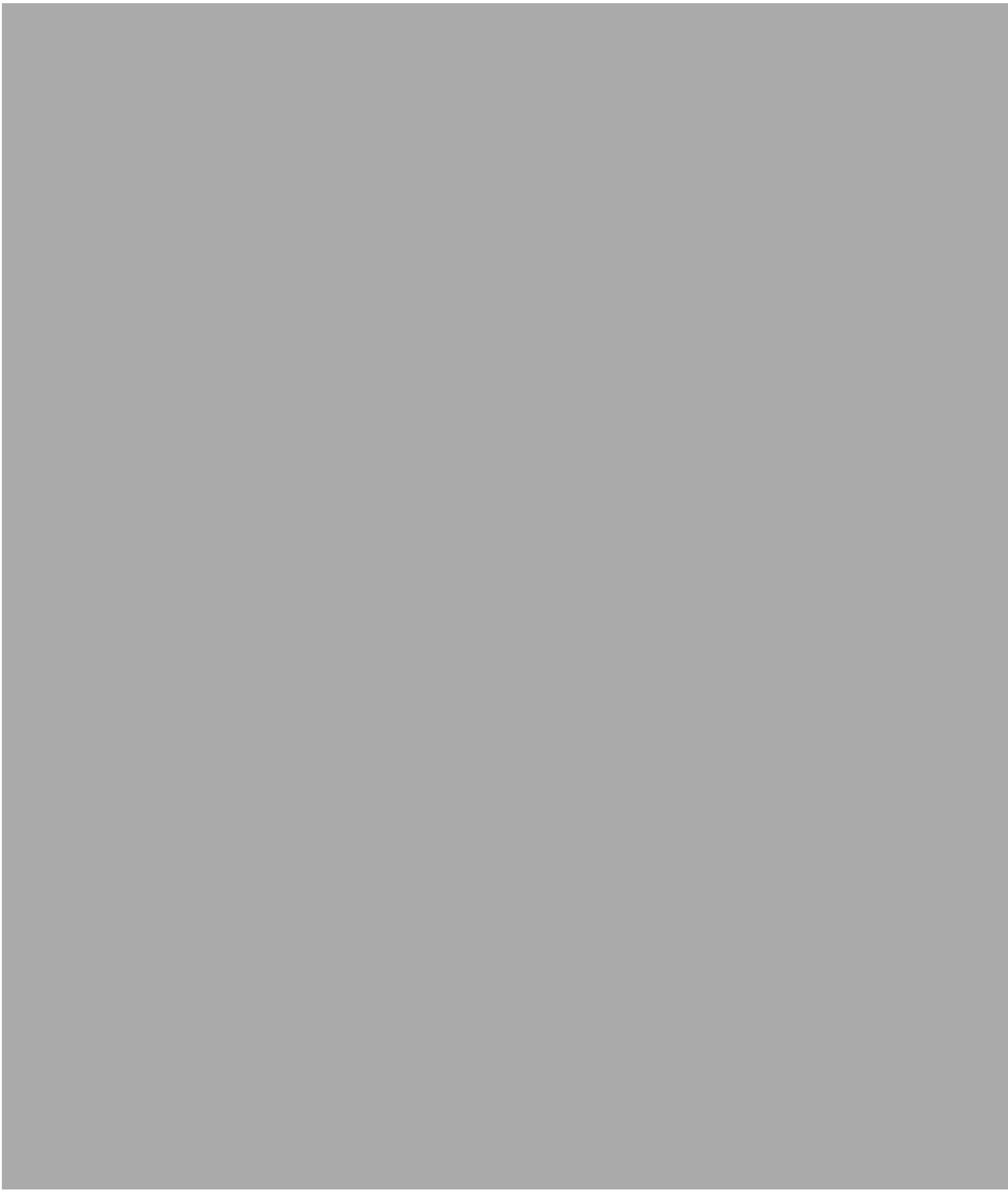
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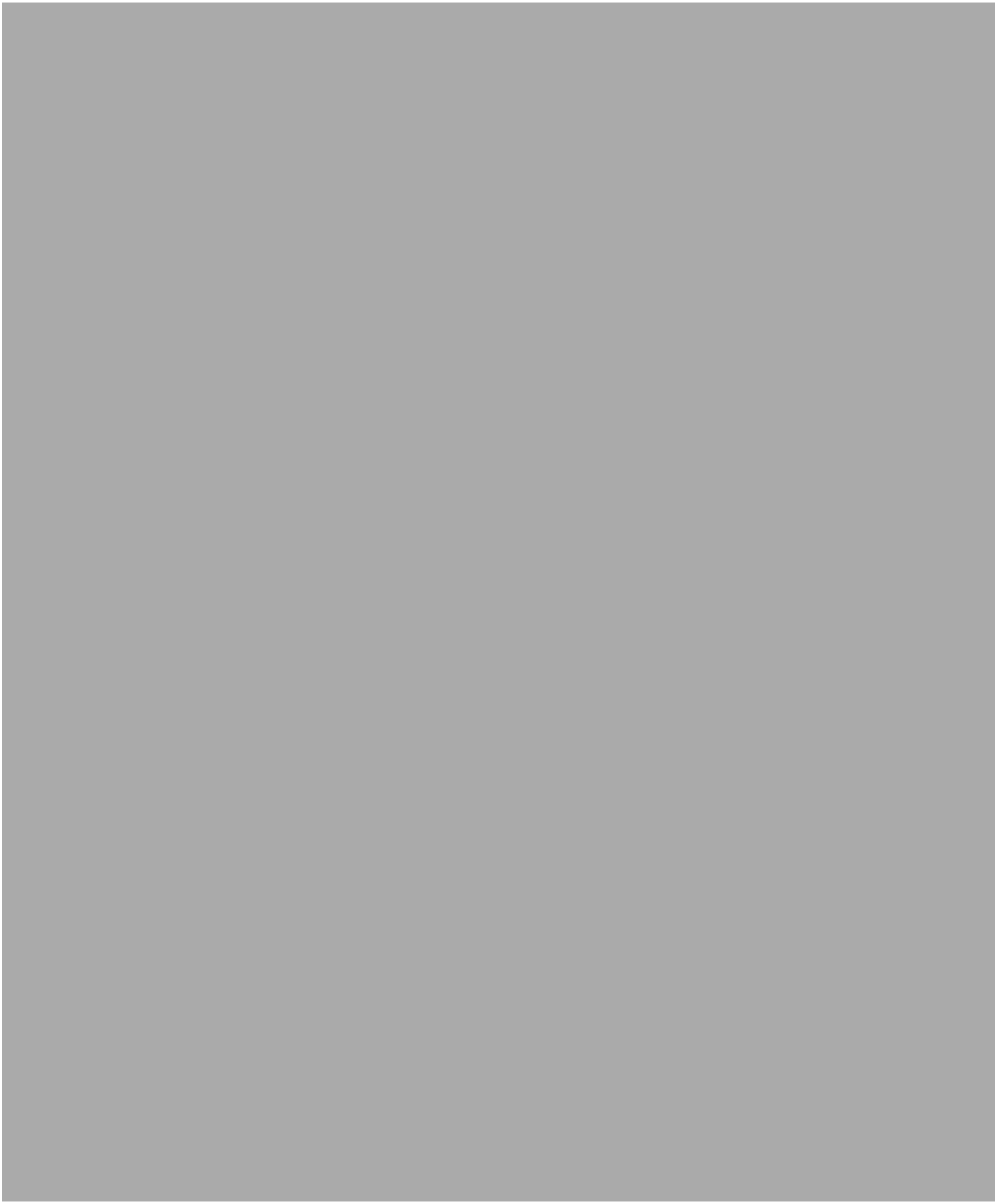
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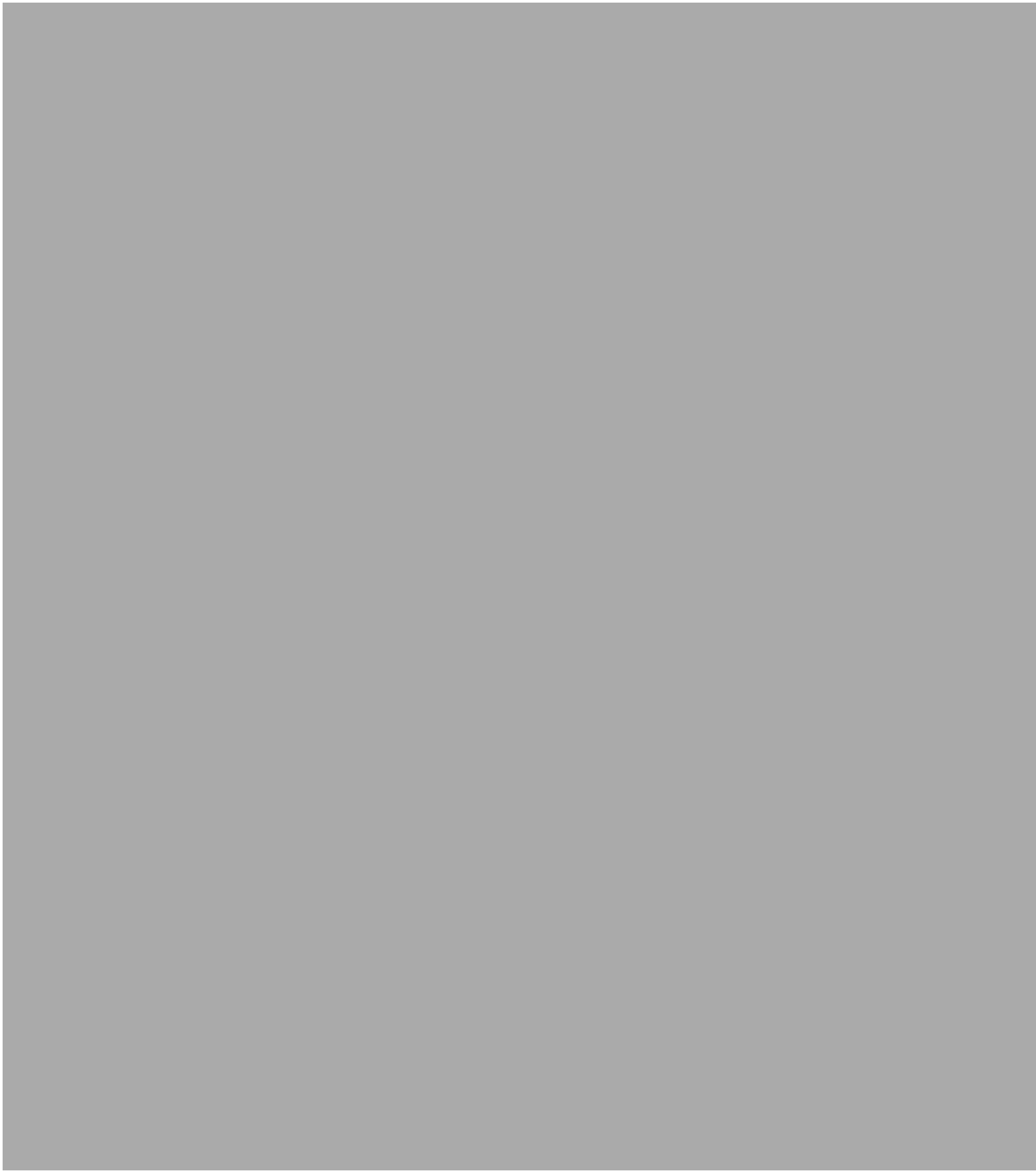


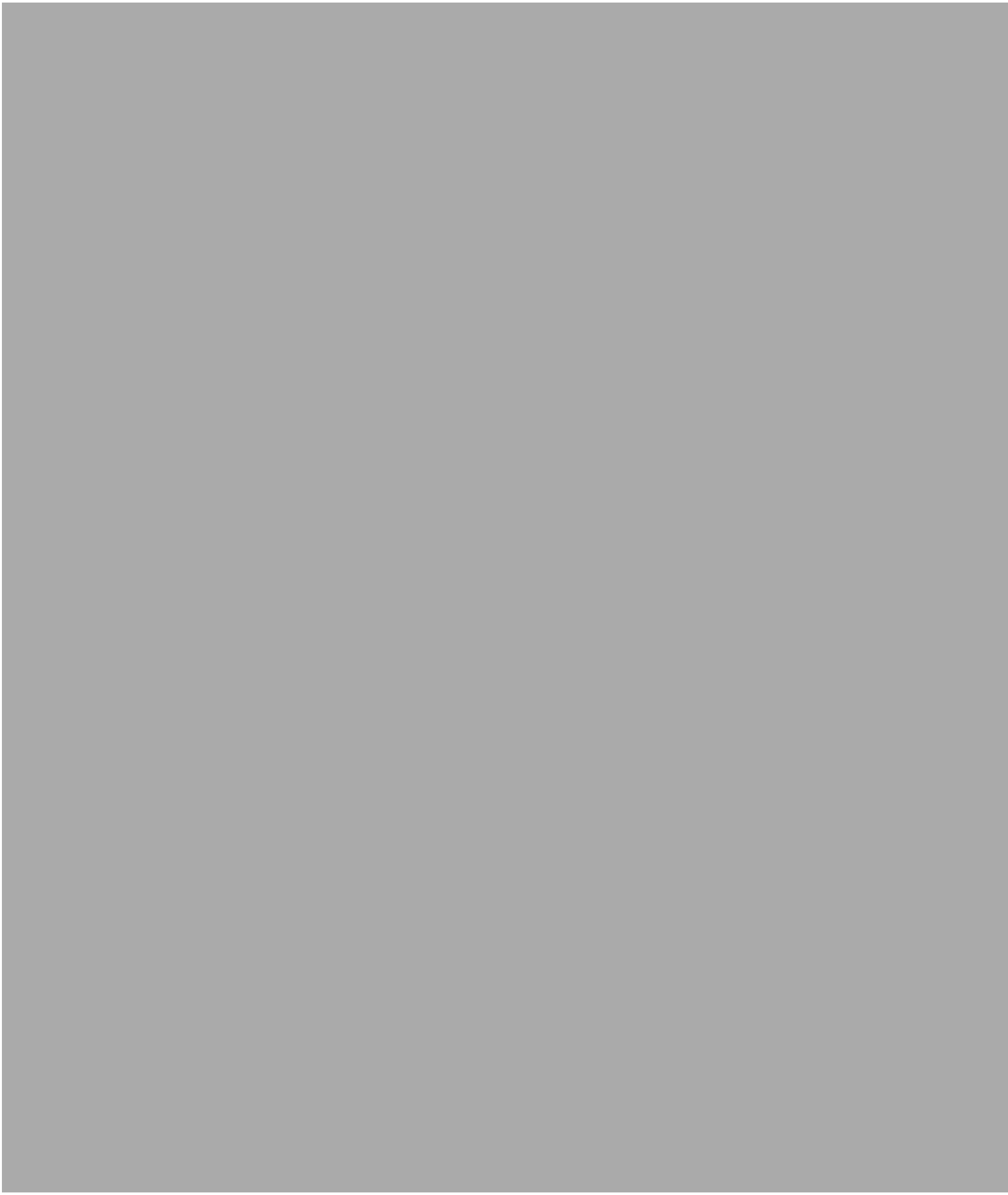


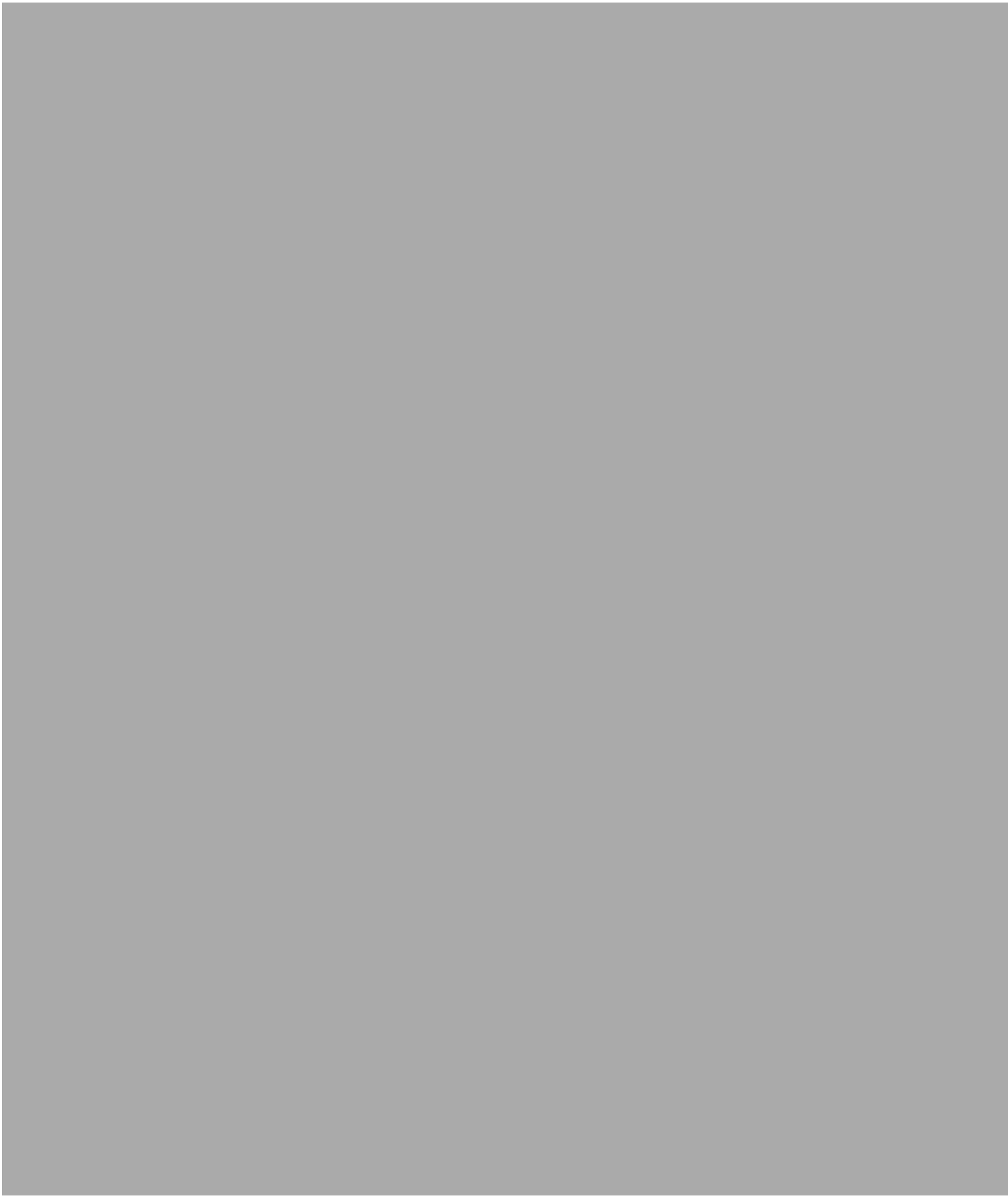


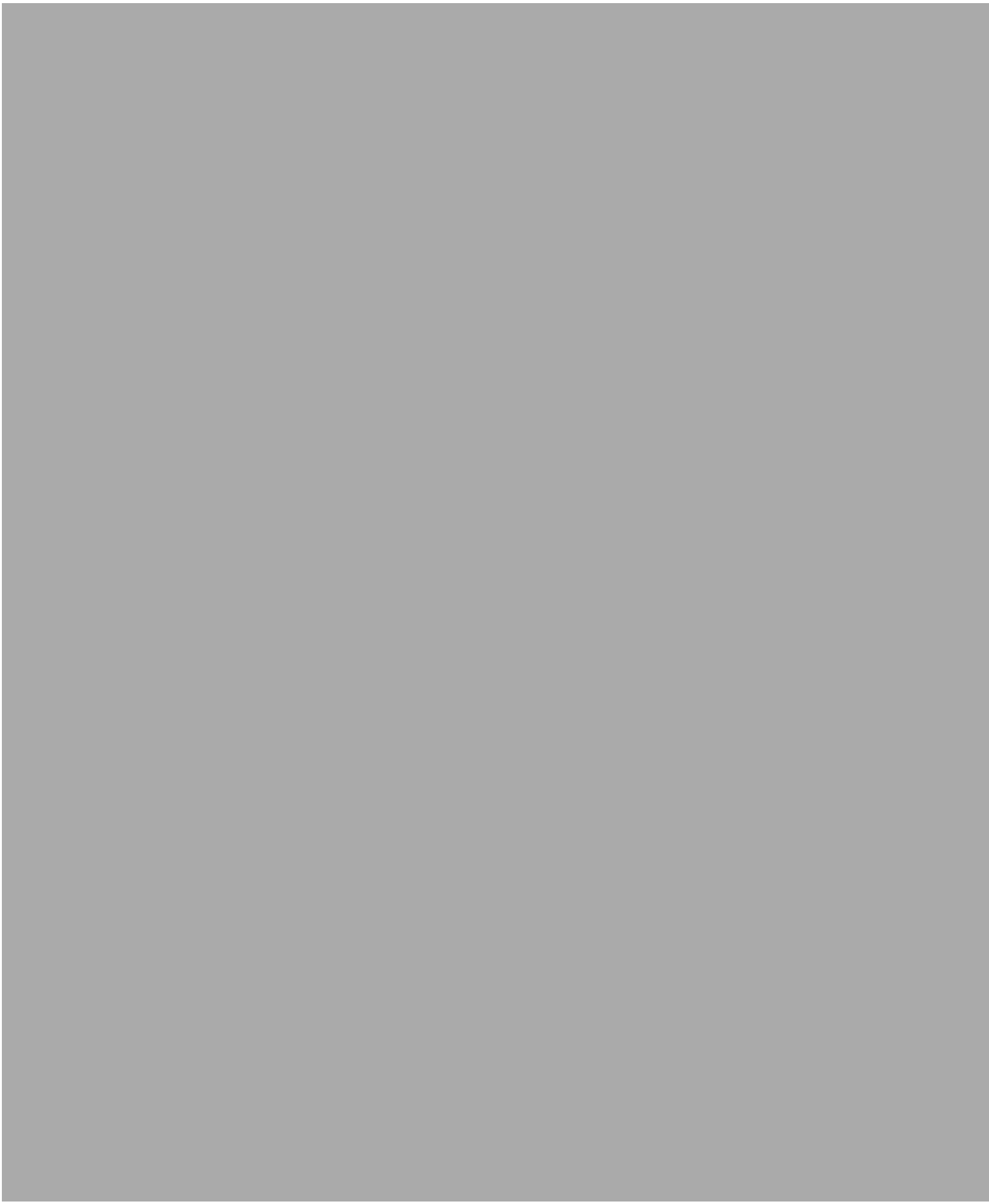


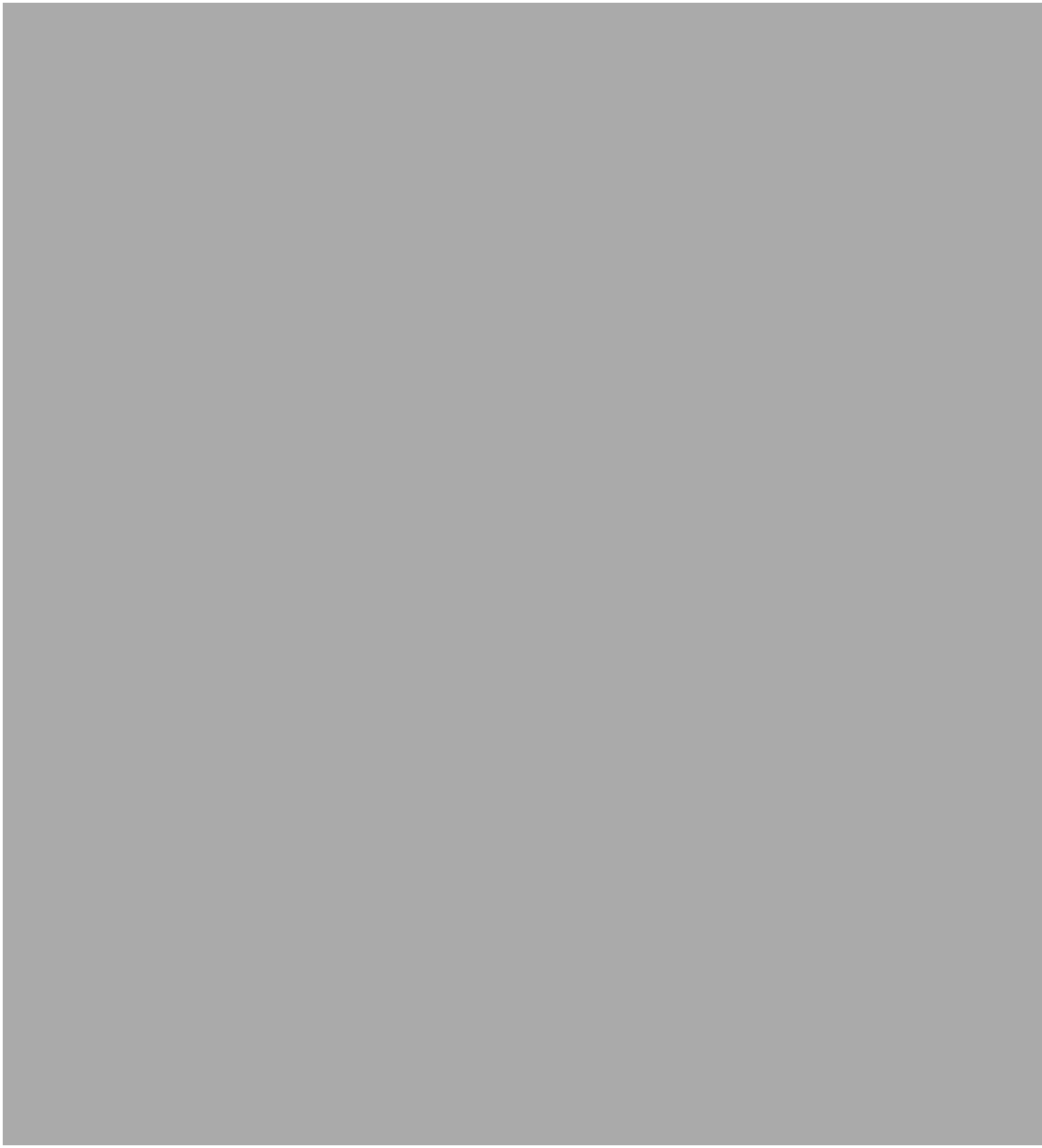


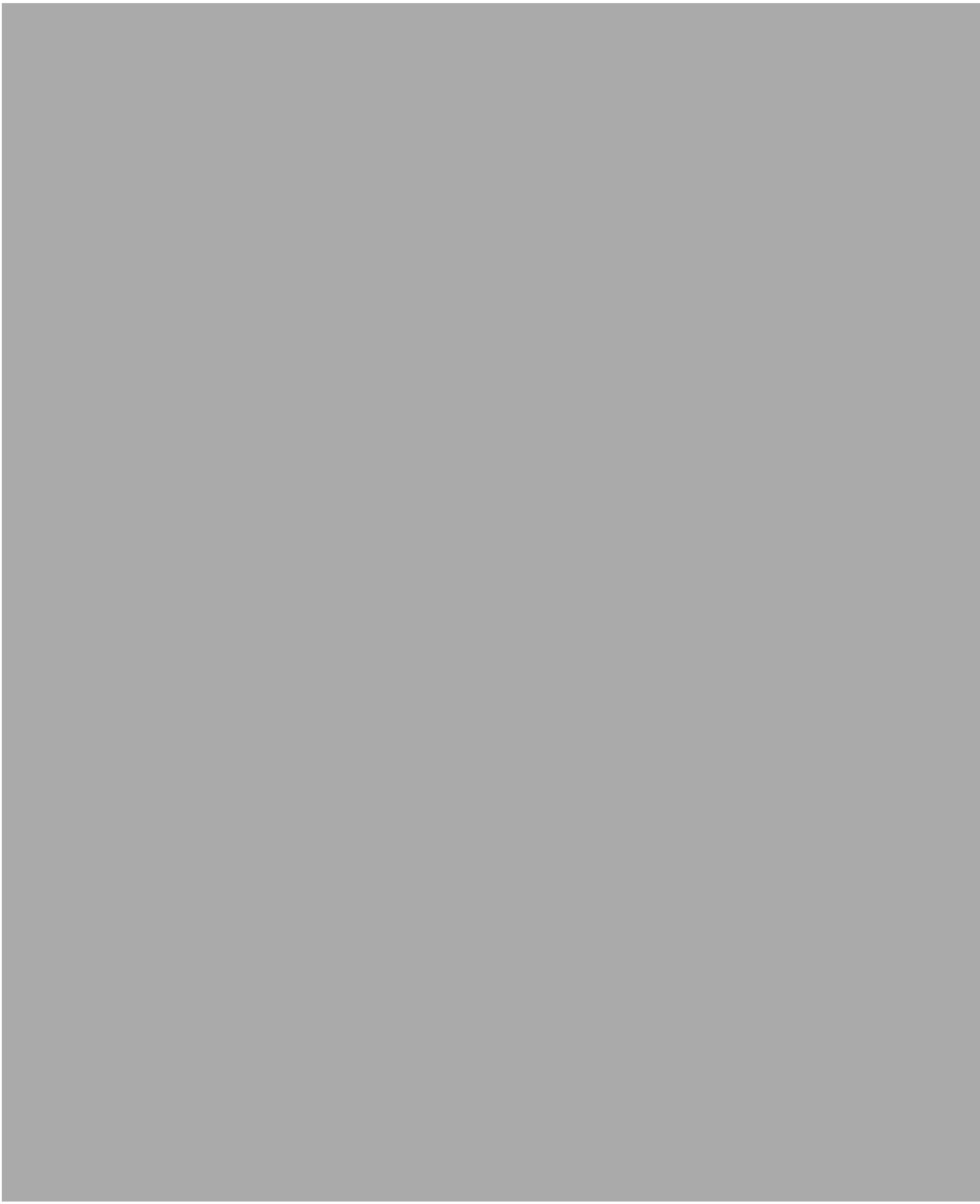














RESEARCH ARTICLE

Doctoral researcher skill development: learning through doing

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Abstract

There has been increasing debate in recent years concerning the need to improve the skill set of Doctoral Researchers (DRs) in order to prepare them for work inside and outside of academia. Valuable discussion on the employability of graduates and the development of transferrable skills is largely focussed on undergraduate students despite the widening of career options for postgraduate research students outside academia. Skill development in current postgraduate pedagogy literature is focussed on specific academic based skills within the research process and does not address the process and content of more generic and transferable skills for DRs. This article explores the organisation of a conference by a small group of DRs and the consequential development and practice of a new skill set outside the usual research process. It presents an effective method for DR transferable, professional and practical skill development.

Keywords: skill development, employability, career options, academic skills

Introduction

Increasing debate has evolved around the importance of effective skill development of Doctoral Researchers (DRs) to prepare them for employment inside and outside of academia. The change in focus of the research degree from an academic apprenticeship to a process-based qualification has highlighted the significance of the development of a wider, and more transferable, skill set during the research degree. Policy directives

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stress the significance of skill development and the Researcher Development Framework (RDF), provided by Vitae, was implemented in 2010 to provide clear guidance on enhancing skill development (Vitae 2010a). This framework has evolved from the Joint Skills Statement (JSS) published by UK Research Councils in 2001 to provide a generic skills agenda for postgraduate student development (Vitae 2013). Despite this focus, the implementation and quality of DR skill development and training is variable (Cryer 1998, Chiang 2011).

While there has been some valuable discussion concerning the needs of students enrolled in doctoral programmes (see Solem & Foote 2009, Fincher 2012, Meadows 2012, Wastl-Walter & Wintzer 2012), DRs remain under-represented as the subjects of skills development initiatives in pedagogical journals. Skill development for employability is largely focussed at the undergraduate level (Cryer 1998), despite the job market for PhDs becoming increasingly varied and often limited for field-specific skills. The applicability of this literature discussion to DR skill development is limited as DRs are operating at a higher level and require skills training to match if it is to be an effective attribute post-graduation (Cryer 1998). At the postgraduate level, discussions have focussed on structured training requirements for research methods (Deem & Lucas 2006) and the role of research culture (Deem & Brehony 2000) to enhance the final output (thesis) and success of completing the research process. The focus on the output rather than continual professional development during the qualification limits the incorporation of more generic and transferable skills into the research process (Gilbert 2004). This is despite a skills framework being endorsed by research councils.

Research on the DR cohort has highlighted the difficulty of incorporating relevant, and appropriately pitched, skills training to a diverse group of specialists and two streams of discussion have emerged around this difficulty. Firstly, the development of generic skills needs to be incorporated into individualistic training to address the specific interpretation of these skills within the field of study (Gilbert 2004, Blaj-Ward 2011). Secondly, and building from this, is the notion of communities of practice training within the DR cohort (McAlpine & Asghar 2010). This approach allows DRs to develop constructive and peer-led training in a context that is relevant to the wider development of the research process. However, both of these literature streams are focussed on the pedagogy of training in the DR community and are lacking clear discussion on *what* students are trained for or the 'curriculum' of skills development (Gilbert 2004).

The case study discussed in this article draws upon these themes and provides an example of effective development of the DR skill base by identifying; (1) which skills were developed, and (2) an alternative approach to professional development through a DR community of practice. An academic-industry-third sector conference was organised by a small group of four DRs at the University of Birmingham in summer 2012. The process of organising a conference was useful for developing skills outside the research process itself but which are valuable both within and outside academia. The skills, specifically transferable, professional and practical, are key attributes for a research student to develop and are more easily accessed through a learning experience rather than structured delivery (Wheeler *et al*. 2011). These skills are arguably central to training DRs for employment and continual professional development but are not fully accessed through the usual research process. Opportunities to undertake extra-curricular activities that are peer-led provide a constructive way of incorporating these aspects of skill development into the DR's programme of research.

Method

On 8 June 2012 the Impact, Exchange and Making a Difference (IEMD) conference was held at the University of Birmingham. IEMD was a successful and professional conference driven by four DRs from the University of Birmingham. The conference was part of an ongoing continuous professional development scheme, Start2Finish Qualitative Methodology Research Group, established in 2009 by a small group of DRs and early career researchers in the School of Life and Environmental Sciences. The idea for the conference was self-led and emerged from discussions within the DR community at the school and beyond about the lack of knowledge in key areas of interest for DRs and their applicability to early career researchers. It was felt that these developments and areas of specific interest for the school community could be uncovered through events run by student groups.

The current provision of training for DRs in the school was designed to provide a base level of awareness of available opportunities for development across the university and externally, driven by the development of individual training needs analysis with supervisors. Required training is sought by the student-supervisor to meet the requirements of the individual and research project. In addition, some research council funded students are required to undertake a structured generic training programme based around research

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methods. Supplementary to this, funding is available for students to develop individual projects that are designed to address specific skill needs in the school. Competitive bids for funding are developed by individual or groups of DRs to address a specific need and success is determined by a college-level panel. A primary activity through this scheme is the delivery of a seminar or conference session. It is partly through this stream of funding that the IEMD conference was developed and the paper provides a case study of the skill development of the four DRs on the organising committee.

Conference theme

The focus on impact emerged from a discussion at Birmingham about Ron Martin's (2001) paper 'Geography and Public Policy: the Case of the Missing Agenda'. This discussion highlighted the fact that many of our DR colleagues felt ill-equipped or under prepared to carry out policy research. This is especially significant as pressure increases within universities to demonstrate research impact outside academia and the push by research councils for impact at the forefront of research programmes and departments. Similarly, the 2014 Research Excellence Framework (REF) states that 20% of their assessment on the quality of individual departments' research will be based on impact (Research Excellence Framework 2011). Geographers in particular are increasingly discussing the different ways their research might be disseminated or obtain greater 'impact' in the world (Hay & Israel 2001, Martin 2001, Bonnett 2003, James 2006). However, much current research fails to unlock its potential to direct, inform and influence policy decisions (Martin 2001). The focus of the IEMD conference was therefore academic impact, and specifically whether in a time of budgetary constraints this could be achieved by collaborating with partners from industry and the third sector. The conference was tailored to DRs to specifically address their role in generating research impact and to effectively bring the early career researchers up to speed on developments in academia for their future careers.

Table 1 Conference details.

Date	8 June 2012
Location	University of Birmingham
Attendees (total)	44
DR attendees	40 (17 external)
External attendees	21 + 2 speakers
Non-academic attendees	4 + 5 speakers

The IEMD Conference

The IEMD conference aimed to be more inclusive than traditional academic conferences; in the spirit of this, third sector, business and industry representatives were invited, along with non-academic staff from the University (Table 1). It was expected that this interaction between academics and non-academic representatives would show how collaboration can be used to achieve impact, and highlight the importance of dissemination of research findings to wider audiences.

The conference was structured to deliver two distinct criteria:

1. Information on the new REF system and the increasing importance of impact in academic research evaluation – through papers and panel sessions on academic understandings of impact.
2. Collaborative engagement - practical workshops on how to work with non-traditional research partners and disseminate research to different audiences.

The morning session focused on academic debates around impact, and featured contributions from academics and university REF coordinators to discuss three key questions:

- How can academics achieve and measure impact?
- What, in the context of your own research experiences, are the obstacles to or best practices that support impactful research?
- At a time when academic resources seem increasingly stretched, what strategies are available to increase academic impact?

The second part of the conference comprised two workshops running simultaneously; one with representatives from third sector organisations and one with representatives from industry and the University of Birmingham's consultancy arm. The workshops were designed to provide access to third and private sector representatives and to generate frameworks for collaboration through cross-party discussion.

The conference finished with a Question and Answer (Q&A) session on public engagement to encourage participants to consider the different ways in which their research might be disseminated and the role of the media in promoting research developments.

Development process

The process of organising the conference involved several key stages.

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1. Funding sources
   The event was funded through two successful bids within the University of Birmingham college and university level funding schemes. The first was from the College of Life and Environmental Sciences Doctoral Researcher-led Research Conferences/Workshops scheme. The scheme was introduced following the withdrawal of 'Roberts funding'. Roberts funding grew out of Sir Gareth Roberts' review SET for Success (Roberts 2002) with the aim of developing postgraduates' employability skills. Although Roberts funding has now stopped many universities continue a similar scheme, such as the funding available at the college level at the University of Birmingham. The second bid was to the Centre for Learning and Academic Development (CLAD), a university wide development team. CLAD's role at the university is to enhance the student experience, but also to offer opportunities to develop the skills base of the overall student cohort. Both funders require DRs to bid for funding by drawing up funding proposals, to liaise with the funders throughout the project's duration and, finally, to evaluate the project after its completion.
2. Development of themes and speakers
   The development of the conference theme is outlined above. The identification of appropriate speakers was a key aspect of the event for the organisers' own professional development as well as the success of the event. Speakers were identified on the basis of their prominence in the field and to develop professional networks externally. Speakers included academics and industry practitioners who could potentially develop solid collaborative relationships for the team.
3. Organisation of event
   Tasks were identified using a Gantt chart and an informal skill analysis of each member undertaken. The purpose of this was to identify strengths and weaknesses in the team and to attempt to find a balance between skill development and existing competencies. The balance was important as the organisation of the conference was in addition to existing research commitments and the amount of time each member could provide to the event was limited. However, the project provided an opportunity for skill development so a conscious effort was made to ensure each member was enhancing or developing their individual skill base. Organising the IEMD event also gave all organisers the opportunity to develop marketing skills – both for the event and personally. From an impact perspective, as well as skill development, the team was conscious to utilise new and innovative methods of marketing, which did prove particularly successful. The conference was advertised through traditional means; university and academic mailing lists, sending emails to university departments and our own website, but it was also advertised through social media and the event was re-tweeted to Professor Alice Roberts' 15,000 followers – a far greater impact than we could achieve individually.
4. Execution of event
   During the event the DR team was engaged in networking with peers and external guests. Between the practicalities of hosting the event, effort was made to engage and build alliances both individually and as an organising team with the spectrum of invited speakers and delegates. Attending and presenting at conferences is an integral part of academic life, and by organising an event a far greater awareness of the process and benefits of such activities is gained.
5. Post event
   The team was extremely keen to continue communication post-event with those who attended and with those who could not. Podcasts, web resources and a competition for research impact case studies from delegates were produced to maintain a set of resources from the event. Undertaking these activities provided a means for the DR team to develop marketing, public relations, ethical and technology based awareness.

These stages provided a structured process of skill development within the organising team.

Results and discussion

The process of organising the conference provided an opportunity to develop skills outside the direct research process. An analysis of skill development across the committee team was undertaken post-event and illustrated a distinct group of skills that had not previously been developed (Figure 1). Data were collected using two qualitative methods. Firstly, throughout the entire period of the organisation of the conference, reflective focus groups were held by the organisers. This enabled the committee to highlight key strengths and weaknesses in our approach, and to elucidate the core learning outcomes and skills development of the organisation process. Part of these reflective focus groups included each member presenting

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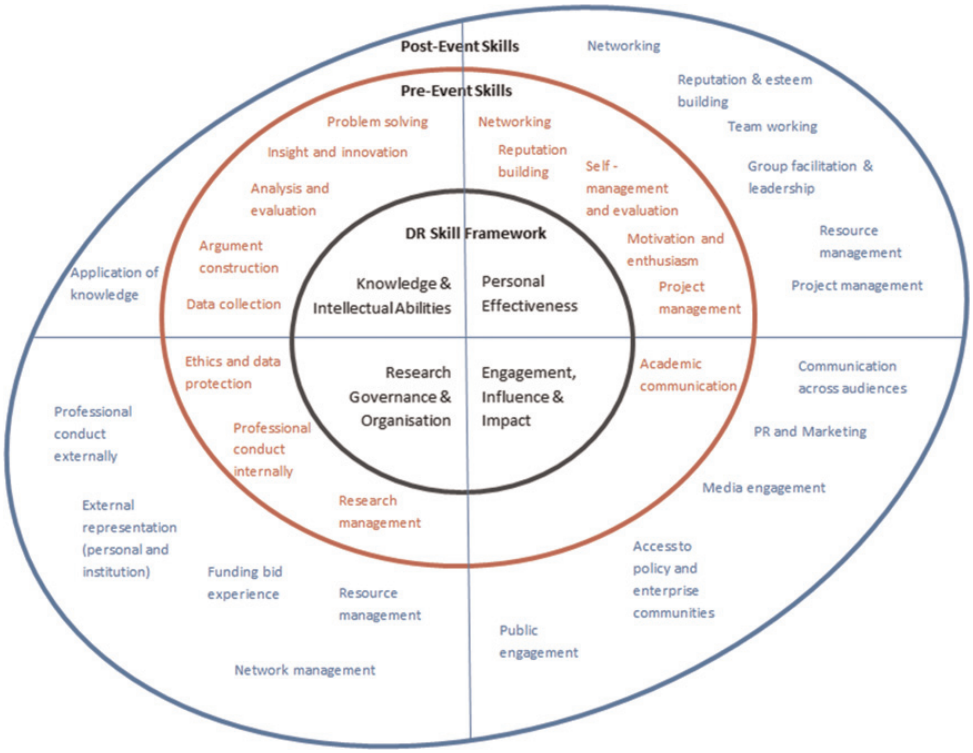


Figure 1 Comparison of skill development in the organising team pre- and post-event (based on Vitae (2010b) Research Development Framework).

their own personal reflective log on their activities to other members. Through recording the key themes and desired learning outcomes in each reflective focus group, we were able to chart our progress by comparing the findings of each focus group with previous meetings.

Secondly, conference participants were given feedback questionnaires following completion of the event. The questionnaires were analysed collectively through further group meetings, which enabled the committee to compare participants' experiences of the event with our own to produce a cohesive picture of the outcomes of the conference.

As part of the RDF by vitae, the Researcher Development Statement (RDS) "*sets out the knowledge, behaviours and attributes of effective and highly skilled researchers*" (Vitae 2010b, p1) and has been used as the basis for an analysis of skills pre- and post-event in the four skills areas:

1. knowledge and intellectual abilities;
2. personal effectiveness;
3. research governance and organisation; and
4. engagement, influence and impact.

The results demonstrate that the organisation of an event provided a distinctly different skill development than the standard research process, as well as enhancing several of the skills already being developed. The new skill development areas are primarily in engagement, influence and impact and research governance and organisation quadrants. In all quadrants, however, new skills were developed. In the personal effectiveness domain, for instance, although there is considerable skill development through the research process in project management, motivation, planning and reputation building, the event organisation continued to reinforce these skills as well as develop more team-focussed skills that are not traditionally primary skills in a solitary research degree. The RDS has evolved to reflect the broader range of skills required by postgraduate researchers and this case study illustrates a method of

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addressing these skill requirements within the research process.

A particularly interesting element is the emergence of a learning experience within the research process. Although a research degree is a 'learning experience' in the wider sense (the PhD process is often negotiated by the individual student and the wider experience as a practicing academic is as valuable as the output), the use of a learning experience for wider skill development is a means of crossing the field-specific divide and bringing together student communities to learn, as in undergraduate fieldwork teaching (Wheeler *et al*. 2011). In addition, the process of a collaborative event provides greater capacity to build creative, leadership and enterprise skills, a new focus of the RDS and JSS (Vitae 2010a, b).

A key difficulty with DR skill development is the range of technical fields of study and backgrounds within a group of DRs (Gilbert 2004, Blaj-Ward 2011). The learning experience of event organisation is a method of incorporating generic skill development within specific research contexts across a diverse group. The topic of an event provides a useful cross-over context for a collaborative exercise, both within specific fields of study but also across them, such as the IEMD event. The committee team had a diverse mix of backgrounds and specialisms, which were reflected to a degree in the development of workshops in the second half of the conference. However, the wider topic allowed the team to combine these tailored elements into a more generic overall concept. In doing so, the event became relevant to the research process as well as an aspect of transferrable skill development.

Wider benefits from the activity are the generation of materials on early career research impact and collaborations between delegates and organisers. Resources, including video interviews with participants and speakers, presentations, workshop case studies and learning outcomes, are all available as e-learning tools on the Start2Finish website. This has facilitated access to learning for delegates who were unable to attend the conference itself. Additionally, participants were asked to provide an individual case study a month after the conference on how their research will now be applied to generate impact. This provided significant feedback on how the conference significantly influenced the way DRs will approach their own research:

> ***"The conference has really made me think about new and exciting ways to distribute my research rather than just through academic journals."*** **(Conference Participant 1).**

> ***"I think the conference was very useful in enabling me to think through what it means to have impact and to which audiences I want to target."*** **(Conference Participant 2).**

The design of the conference provided a unique opportunity for researchers to interact with a range of specialists to discuss the issue of research impact. The conference initiated and strengthened relationships between academia and the wider community, and our evaluation identified a number of cases where potential collaborative projects took root as a result of the conference. The need for an interactive relationship between academics and businesses was a major conclusion from the conference:

> ***"Academics, the outside world is hungry for what you know!"***
>
> **(Mike Bentley, Bentley Associates EU Ltd).**

Conclusions

This article demonstrates the valuable skills DRs gained from conference design, funding bids and collaborative project development that are transferrable across industries. The IEMD conference was more open and inclusive than traditional academic conferences by providing a platform for academics and the outside community to explore the issue and approaches to research impact. The inclusiveness of the topic allowed a more diverse group of DRs to undertake the project because it tapped into each individual's specific research process as well as build networks across communities. These skills are interpersonal and transferable, which contributes to both our academic toolkit and further professional life outside academia.

The application of skills is a key aspect of skill development and the organisation of an event that is both research and skill relevant provides an opportunity for this within the traditional research process of PhD study. There has been a call for a "...change in how graduate students are prepared for professional careers, with concerns being raised about the inability of many new graduates to apply their knowledge and skills to serve a broad range of societal needs" (Solem & Foote 2009, p13). By integrating a learning experience within the research process the application of key skills can be developed and clearly demonstrated post-study. Evaluation of the conference demonstrates one method in which DRs can develop their skills and continue to learn within higher education.

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