AN ANALYSIS OF KNOWLEDGE FLOWS THROUGH RESEARCH COLLABORATION IN ASEAN AND CHINA

By

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ABSTRACT

Knowledge flow literature indicates Global North (GN) countries have taken a dominant role in knowledge production. Meanwhile, Global South (GS) countries depend greatly on GN countries for knowledge flows and broader unbalanced participation in knowledge creation. This study focuses on GS countries from the Association of Southeast Asian Nations (ASEAN) and China. It aims to understand the structure of knowledge production, the determinant factors and how they affect innovation.

The network structure has been analysed using Social Network Analysis (SNA). Determinant factors of international research collaboration (IRC) are estimated through Negative Binomial and Poisson panel regression. Lagged panel data regression models have been estimated to measure the effect of international knowledge flows on country-level innovation creation.

The study has contributed by delivering GS perspectives on knowledge flows literatures. The network structure of international research collaborations experienced little change over 11 years (2006–2016). Although ASEAN countries and China have demonstrated high dependency on knowledge flows from GN countries, this has not brought significant advantages in generating innovation. The determinant factors of IRC demonstrate different patterns than in GN countries, particularly the importance of colonial ties, income economies and scholarly outputs.

Keywords: collaboration, research, ASEAN, China, GS countries

Dedicated to:
Our Parents, Tita , Adlan and Adlina

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Bahtiar Rifai

LIST OF ABREVIATIONS

ARISE	ASEAN Intellectual Property Rights
AMS	ASEAN Member States
AUN	ASEAN University Network
AWGIPC	ASEAN Working Group on Intellectual Property Cooperation
APEC	Asia Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
CBD	Central Business District
COSTI	Committee of Science, Technology and Innovation
EU	European Union
FDI	Foreign Direct Investment
GN	Global North
GS	Global South
GDP	Gross Domestic Product
GNI	Gross Net Income
HEIs	Higher Education Institutions
HDI	Human Development Index
ICT	Information and Communication Technology
IT	Information and Technology
IP	Intellectual Property
IPA	Intellectual Property Academy
IPR	Intellectual Property Rights
IRC	International Research Collaboration
LDCs	Least Development Countries
MNC	Multinational Companies
NB	Negative Binomial
NAFTA	North American Free Trade Agreement
R&D	Research and Development
RISET-Pro	Research and Innovation in Science and Technology Project
SCO	Shanghai Cooperation Organisation
SMEs	Small Medium-sized Enterprises
SNA	Social Network Analysis
SOEs	State-owned Enterprises
SDGs	Sustainable Development Goals
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
US	United States
WoS	Web of Sciences
WDC	Weighted Degree Centrality
WIPO	World Intellectual Property Organisation

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CHAPTER I
INTRODUCTION

1.1 Background of the Study

Knowledge has become a fundamental element in the development of nations since many productive sectors and economic activities have been transformed into knowledge-based activities. External knowledge, particularly from international sources, is demanded by many countries to create new knowledge and grow internal innovation (Jaffe and Trajtenberg, 1999; Hassan and Haddawy, 2013) due to their limitations in generating or improving internal knowledge capacity. Awareness of external knowledge has been continuously growing due to its role in determining total outputs, national growth and the competitive advantages of a country (Williams and Balaz, 2008).

Knowledge diffuses across nations generally via five main channels: international trade, foreign direct investment (FDI), international research collaboration (IRC), migration, and licensing (Fagerberg, Srholec and Verspagen, 2010; Cappelli and Montobbio, 2014; Lengyel and Leydesdorff, 2015; Lengyel and Eriksson, 2017). Trade and FDI conventionally have been recognised as the primary instrument of knowledge flows (Williams and Balaz, 2008) due to knowledge embodied in goods and capital. Nevertheless, trade and FDI seem to bring little effect on knowledge spillover within the nation (Jaffe and Trajtenberg, 1999) which implies a dependency on foreign equipment or foreign capital instead of localising knowledge. Similarly, licensing (widely acknowledged as a technology transfer channel) has provided less opportunity to acquire external knowledge. In the meantime, the complexity of migration leads to the risk of uncertainty between costs and advantages for knowledge diffusion, particularly

for countries that have not implemented regional intregation policy by developing a common market for goods, labour, capital and services (Argote and Ingram, 2000; Abreu, Faggian and Mccann, 2015). On the other hand, IRC offers flexibility, responsiveness, and sustainability to produce new knowledge internally (Shannon & Weaver, 1994 in Szulanski, 2000). In addition, collaborative research activities represent a learning process which is essential for easing knowledge transfer. Therefore, collaborative research holds a position of fundamental importance in attaining sustainable knowledge flows.

In the meantime, Global North (GN) countries have been highly successful in producing new knowledge through intensive research and development activities. This has given GN countries global recognition as prominent producers of academic knowledge (Binka, 2005), research and development (Huggins, Demirbag and Ratcheva, 2007; Crossley, 2014), and innovation (Crescenzi, Rodríguez-Pose and Storper, 2007). Unfortunately, in other parts of the world, some countries in the Global South (GS) encounter lack of capacity to produce new knowledge due to internal limitations (Knobel, Simões and De, 2013). This has encouraged GS countries to undertake collaboration with GN countries, and at the same time GN countries continue acquiring external knowledge by collaborating with various different sources in order to produce new knowledge. Unequal capacity, experience, and performances in producing knowledge and innovation have potentially led to some issues, such as high dependency of GS countries on GN countries and broader unbalanced participation in knowledge creation. In the meantime, research investigating IRC between GN countries and GS countries reveal that they popularly undertake bilateral and multilateral cooperation (Arunachalam and Doss, 2000). This study contributes to the literatures by presenting empirical experience of knowledge production in countries from GS represented by a region (neighbouring countries group officially bounded through intergovernmental cooperation) in Southeast Asia.

1.2 Genesis of the Thesis

Undertaking this research was motivated by two main rationales: a personal perspective and my academic experience in regard to previous work. I was born in a small city (in Yogyakarta, Indonesia) and raised in a rural area. Since land prices in the central business district (CBD) and urban areas have continuously increased, some Higher Education Institutions (HEIs) decided to relocate their activities to the more rural areas where the land price is still affordable. The presence of new HEIs had regenerated the local economy and stimulated further development, such as infrastructures, health services and energy which attracted more people to come and live there. These have resulted in shifting the category of my hometown from a rural area to be a more urbanised area. Therefore, some significant changes have indicated the effect of HEIs on empowering the local economy and development.

Similarly, being a researcher in a government body and working in a regional economic field widened my knowledge on local economy generators. My master's thesis (2009–2010) is about interlinking industrial estates where most of the multinational companies (MNCs) are located, to local economy activities. This research provided understanding of how to generate the economy through implementing a trickle-down effect by collaboration between MNCs and local small medium-sized enterprises (SMEs). This strategy is expected to be able to ease knowledge spin-off to local businesses and stimulate local innovation. In regard to my job, I continued undertaking research to develop a synergistic model between SMEs and state-owned enterprises (SOEs) and implemented several projects in rural areas in Sumatera and the Java islands. These were facilitated by local government and SOEs. However, the combination of my subjective experience and my professional experiences has encouraged me to examine the

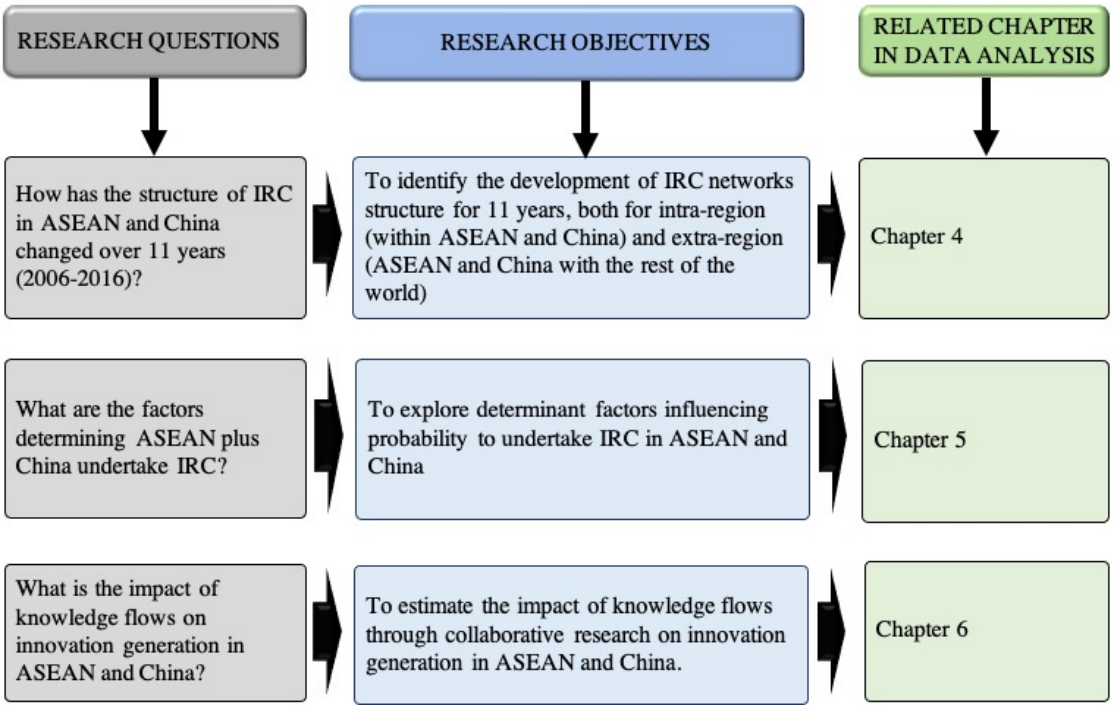
impact of universities on the economy and innovation through different mechanisms like knowledge transfer.

During my PhD journey, I began realising that collaboration between universities at global level is obviously manifested through collaborative research which is one of the instruments of knowledge flows. This provides me with a broader understanding of IRC, which consists of complex elements, such as motivations, the engagement process, key factors of successful collaborations, potential issues of undertaking IRC, and some advantages. This research project has illustrated how GN–GS collaborative research has been implemented and encourages the redesign of mutual collaboration in the future.

1.3 Research Aims and Objectives

The broad intention of this study is to investigate knowledge production through collaborative research in the Association of Southeast Asian Nations (ASEAN) and China as representative of GS countries and also in contributing to academic literature by delivering GS countries' perspective on knowledge flow literature. The aims of this study are to investigate:

- How has the structure of the IRC network in ASEAN and China changed over 11 years (2006–2016)?
- What are the factors determining ASEAN and China to undertake IRC?
- What is the impact of knowledge flows on innovation generation in ASEAN and China?



In regard to the research questions, the intention of this study is to attain the following objectives:

- To identify the development of the IRC network structure of the intra-region (within ASEAN and China) and extra-region (between ASEAN and China and the rest of the world) during 11 years (2006–2016).
- To examine the determinant factors influencing the probability to undertake IRC in ASEAN and China.
- To estimate the impact of knowledge flows on generating innovation in ASEAN and China.

1.4 Research Method

This research project investigates the production of co-authored publications in order to examine knowledge flows in ASEAN and China. Co-authored papers represent knowledge exchange between international scholars, particularly involving a direct learning process, the

transfer of ideas and the quality process (Ponds, van Oort and Frenken, 2007a; Hou, Kretschmer and Liu, 2008; Boshoff, 2009; Fari and Ocholla, 2016). Co-authored publications data was collected from the Scopus database through the SciVal website[1] for 11 countries (Indonesia, Singapore, Malaysia, Thailand, Philippines, Vietnam, Cambodia, Laos, Myanmar, Brunei Darussalam, and China) over an 11 years' duration (2006–2016).

During the research, three different approaches have been employed to achieve the three main objectives. *First*, Social Network Analysis (SNA) has historically been utilised to identify the structure of networks in various research areas within economic geography and regional studies such as research collaboration, knowledge transfer and innovation since SNA seems the most appropriate approach to examine social interactions (Ter Wal and Boschma, 2009; Fritsch and Kauffeld-Monz, 2010; Gluckler and Doreian, 2016; Guo, Zhang and Guo, 2016; Glückler and Lazega, 2017). *Second*, since IRC activity is structurally similar to international trade, a Gravity Model was utilised to examine interaction between two different countries. This approach has been broadly adopted in research collaboration studies due to its ability to estimate country characteristics as masses and separation between two countries in determining probability to undertake collaboration (Sutter and Kocher, 2004; Tsukada and Nagaoka, 2015; Scherngell and Hu, 2017). *Third*, the effect of knowledge flows on innovation generation is estimated through lagged panel data.

1.5 Structure of the Thesis

The contention of the research is proposed across seven chapters. The thesis begins with a chapter of introduction and the following six chapters are described below:

[1] https://scival.com/benchmarking/analyse

Chapter 2: Literature Review

This chapter outlines fundamental concepts of knowledge, knowledge flows and its impact on innovation to bring understanding of the relation between knowledge and innovation. It continues with explaining research collaboration and GN countries–GS countries cooperation in order to examine research gaps in the existing academic literature. Furthermore, the concepts of SNA and region are also discussed to help investigate the structure of collaborative research in ASEAN plus China as a region (group of countries).

Chapter 3: Research Methodology

This chapter defines the research design of the study, type of data and data collection, approaches and measurements, hypotheses development, data preparation and processing of data.

Chapter 4: The Structure of Collaborative Research Network in ASEAN and China

The first empirical chapter identifies the structure of the collaborative research network ASEAN and China with the rest of the world. This is undertaken to scrutinise how the structure behaves with different collaborative research partners. The structure is identified using four measurements: Weighted Degree Centrality (WDC), Network Density, and Community Structure.

Chapter 5: Determinant Factors Influencing IRC in ASEAN and China: Evidence from a Panel Gravity Model

The probability of undertaking IRC seems to vary among ASEAN member states (AMS) and China, which is reflected through the hierarchy of the collaborative research structure. The

likelihood of conducting IRC may be influenced by several factors that are encountered differently in every country within the region, for instance country characteristics, geographical proximity, and non-geographical proximities. These have been elaborated through econometric modelling estimated using Negative Binomial and Poisson gravity model panel regression, as the nexus of the second empirical chapter.

Chapter 6: The Impact of Knowledge Flows on Innovation Generation in ASEAN and China

Following up with two previous empirical chapters, this third empirical chapter measures the effect of knowledge flows on generating innovation by distinguishing the source of knowledge flows: intra-regional and extra-regional collaborations. Patents have been employed as a proxy for innovation generation since novelty is the main element in the awarding process of patents. The impact of knowledge flows on innovation has been estimated using lagged panel data regression.

Chapter 7: Conclusions

Some reflections on how knowledge flows are seen from GS countries' perspective are offered within this chapter. It presents an overview of the empirical chapters on how knowledge flows impact on ASEAN plus China. In addition, the chapter summarises the findings in respect to the research questions, and also elaborates on the contributions of this study, its limitations and potential indications for further studies.

CHAPTER II
LITERATURE REVIEW

2.1 Introduction

The importance given to the role of capital in development and the economy has shifted over the years. The conventional paradigm has perceived money as the primary source of growth and increasing productivity. Capital accumulation recognises as a powerhouse accelerating development. Therefore, many countries have implemented it by inviting foreign direct investment (FDI) to support their national development. In the meantime, the importance of knowledge has been growing significantly. Knowledge is the leading source for innovation activities that can accelerate growth and increase competitiveness, mainly when many economic activities depend on knowledge as the primary development base. The knowledge-based economy has shifted the paradigm from the pursuit of capital accumulation to knowledge accumulation as the backbone of economic activities and development.

Knowledge accumulation is associated with higher productivities. Knowledge influences productivity, obviously through two main instruments: labour and technology. Knowledge, which is an attribute of education and research activities, determines human resource quality. It crucially drives productive sectors and the economy. An intensive research and development activities have strengthened knowledge creation and innovation development. Innovation is the core of three industrial activities, mainly supporting the production process (through advanced technology and modern machinery), influencing management systems to be more efficient, and increasing sales. A combination of the higher quality of labour quality and a rapid innovation generation simultaneously determines the industry's productivity.

This chapter aims to explain the concept of collaborative research, determinant factors of international research collaboration (IRC), and transformation of knowledge into innovation. These have been arranged in three sub-chapters and finish with a concluding discussion. Conceptualisation from theories helps develop a framework to understand GS countries' knowledge production in dimensions of the structure, determinant factors, and innovation.

2.2 Collaborative Research and Concept of Region

The combination of exogenous knowledge, internal capacity, market conditions, and national policies are conducive to grow innovation (Huggins and Thompson, 2014; Bergé, Wanzenböck and Scherngell, 2017). These make science a powerful force for the economy that accelerates development, although there is a price attached: the price to create, price to transfer, and price to transform into innovation (Price, 1986; Moed, Glänzel and Schmoch, 2004). Many approaches can be employed to acquire external knowledge, like labour migration, international trade, FDI, licensing, and research collaboration (Montobbio and Sterzi, 2013; Lengyel and Leydesdorff, 2015; Lengyel and Eriksson, 2017). It presumes research collaboration that involves knowledge producers (universities, research centres, private companies) gives more sustained knowledge acquisition processes than other transmissions, such as the economy (imports) and migration. This sub-chapter will focus on research collaboration that is estimated using the number of co-authored publications.

This sub-chapter consists of four sections and aims to provide a brief definition of the concept of research collaboration and a region. It begins with the concept of research collaboration, intra-region research collaboration, and extra-region collaboration. The following section explains the region's concept and continues with the Global North (GN) countries and the Global South (GS). The importance of research collaboration for global science and knowledge

development will be explained along with international collaboration between GN countries and GS countries.

2.2.1 Concept of International Research Collaboration (IRC)

Collaborative research is the key to advance knowledge and science since it offers an opportunity for scholars to exchange their ideas and knowledge, practice similar methods, utilise common resources, and therefore they can leverage the members' performance (De Stefano *et al.*, 2013; Foley and Della Sala, 2014). Also, undertaking collaboration potentially increases technological capacity through interdisciplinary research and experts from various backgrounds (Jeffery, 2013; Rusly, Yih-Tong Sun and L. Corner, 2014). Interdisciplinary science has overcome global problems that have been more complex (Hara *et al.*, 2003).

However, global development may bring externalities that demand to address. Research partnerships may improve country collaborators' capacity to achieve their goals by receiving information and funding, accessing productive resources, utilising equipment, and technical assistance from the experts. It is relevant to sustainable development goals (SDGs) to reduce global poverty, disparity, and unemployment. Moreover, collaborative research potentially accelerates the economy and development through innovation. These will bring more excellent opportunities for general development when collaboration is conducted on a large scale and involves several partners. Consequently, collaboration requires synergy in processes and cooperation among the partners.

Collaboration conceptually represents social interaction and establishes a network structure from the participants' connectivity. Abbasi et al, (2012) found how social interaction has dominated the collaboration process among different organisations. The process generally is

undertaken using informal channels, like friendship, or interaction between colleagues with similar backgrounds or contacts from scientific meetings, although it may be through formal channels, like agreements or Memorandum of Understanding (MoU) (Georghiou, 1998; Dahl and Pedersen, 2004; Ostergaard, 2009; Jeong, Choi and Kim, 2014). Research collaboration is a complex process since it involves social action to streamline different ideas (Mêgnigbêto, 2013). A research collaboration requires communication repetition, a flexible interaction method for coordination, active and progressive collaborators, and a crucial research topic to respond to global dynamics (Huggins and Thompson, 2014). Collaboration also represents a social development process whereby individuals' efforts and capital accumulate and create new knowledge (Jentsch and Pilley, 2003). Therefore, collaboration is dealing with physical interactions and the social aspects to build reciprocal and robust cooperation. The social process is essential at the initial stage to develop trust among contributors as the baseline for the partnership. In other words, having a robust foundation will determine successful collaboration in many schemes.

Collaboration activities generally can be undertaken through two primary schemes: a formal agreement between institutions and casual or informal cooperation between individuals. An informal engagement, which has been popular in collaboration, offers flexibility and efficiency in bureaucratic processes, while formal agreement gives more sustainable cooperation since it is relatively low risk for cost and research failure (Georghiou, 1998). Furthermore, these forms may apply in three types of research: pure academic research, applied research, and a combination of them (Caiazza, Richardson and Audretsch, 2015). Collaboration in scientific (basic) research is usually led by universities, while private research centres and industries mostly undertake applied research. The collaboration of universities and industries aims to simultaneously achieve academic innovation and business excellence (Ribeiro *et al.*, 2014;

Caiazza, Richardson and Audretsch, 2015). Nevertheless, scientific research is essential for knowledge development.

At the implementation level, the spectrum of scientific partnerships can also be seen from collaboration on the preparation of research proposals, joint research, and publishing academic papers in conferences and journals (Van Raan, 1998; Abbasi, Chung and Hossain, 2012). Thanks to developments in information technology, collaboration should not demand face-to-face communication every time collaborators need to communicate, as this conduct through indirect interaction. ICT development has been easing communication between actors separated by distance, such as teleconferences, email, video calls, and other communication products.

However, scientific collaborations have been more popular during the last decades compared to many other collaboration forms. Academic collaboration is defined as mutual-cooperation between researchers to elaborate resources, knowledge and achievement (Patel, 1973; Olechnicka, Ploszaj and Celinska-Janowicz, 2019). Social interaction helps to convey scholars' interests and expertise into bilateral cooperation as part of the collaboration process to achieve academic objectives (Abbasi, Altmann and Hossain, 2011). Collaboration also identifies as a process to share experience, skills, and capability between two and more scholars to generate new general acceptance that none of them had possessed before (Schrage, 1995). Shared understanding between researchers stimulates new knowledge resulting from various elaboration processes (Gazni and Didegah, 2011). Collaborative research can potentially be a benchmark (baseline) for further cooperation, like patent collaboration, manufacturing, investment, and trade (Gazni and Didegah, 2011). Collaborative activities is seen as a natural response of scholars to engage with the other scholars, resulting in improved researchers'

productivity, institutions, and global science as further impact (Lee and Bozeman, 2005). From the various definitions, there are two essential features of collaboration: sharing efforts to achieve common objectives and knowledge transfer processes (Abbasi, Hossain and Leydesdorff, 2012). It means that collaboration can simultaneously work if similar interests exist between collaborators (Katz and Martin, 1997; Bergé, Wanzenböck and Scherngell, 2017). Therefore, academic collaboration engage eight essential elements as the main characteristics: trust and understanding; mutual-cooperation; sharing resources; involvement of a minimum of two contributors; learning process; knowledge flow, achieving a shared goal; resulting in new knowledge and innovation as the final outputs.

An illustration of a collaboration network would be like a multilayer cake, consisting of several types of collaboration and interlinking multi-levels of actors (Jarneving, 2010). The connectivity between actors creates a distinguishable pattern determined by the group of collaboration partners. The level of collaboration basically can be distinguished into three clusters: bottom (scholars), middle (institutions), and higher (nations) (Hou, Kretschmer and Liu, 2008; Grillitsch, Tödtling and Höglinger, 2015). Analysis of collaborators' various characteristics and the impact of collaboration reveals six levels of actors: individuals, groups, departments, institutions, sectors, and state. From this perspective, the types of interaction among collaborative partners can be grouped further as intra collaboration or inter collaboration (Katz and Martin, 1997; Van Raan, 1998; Lu and Feng, 2009) (see Table 2.1).

Table 2. 1 Level of Actors and Type of Collaboration

Level	Collaboration types	
	Intra	Inter
Individual	-	Between Individuals
Group	Between individual within same research group	Between groups (within same department)
Department	Between individuals or group within same department	Between department (within same institution)
Institution (affiliation)	Between individuals or department within same institution	Between institution
Sector	Between institution within the same sector	Between institution from different sectors
Nation	Between institution within a country.	Between institution from different countries

Source: Katz and Martin, 1997

Based on the types of interaction, collaboration in research, as reflected in publications, distinguish as within (intra) community connectivity and global connectivity (Katz and Hicks, 1997). However, the dichotomy between inter and intra collaborations may be challenging to differentiate in some situations, particularly when inter collaboration and intra collaboration appear simultaneously; for instance, when a publication involves two authors from two different institutions of a country and one foreign author. Theoretically, there are two possibilities for this situation: it can be concluded as a mixture of collaboration (intra and inter), or international collaboration because it involved one institution from abroad. Different categories may not be an issue when the identifying process consistently uses the same parameters. Selecting the collaboration category helps to measure the collaboration work precisely.

Collaborative research also recognises the modes of how collaboration is implemented. The modes of collaboration relate to how collaborative partners undertake the relationship between them. There are two modes: a strong relationship which is associated with specialisation of collaboration that gives room for creativity and imitation between collaborators, and a weak

relationship which gives greater autonomy for collaborators allowing improvisation in a particular research field (Olechnicka, Ploszaj and Celinska-Janowicz, 2019). Thus, modes of collaboration will determine how collaborative works generate many advantages.

International collaboration previously measures in many approaches: frequency and duration of international calls, flights, and correspondence with overseas colleagues (Melin, 2000). However, the most evident and approachable academic collaboration parameter is co-authored papers (Abbasi, Hossain and Leydesdorff, 2012). This method has been believed as an accurate method to count the incidences of collaboration (Davidson Frame and Carpenter, 1979; Ye, Li and Law, 2011; Li, Liao and Yen, 2013). Co-authored papers generally involve either several authors or many academic institutions (academic authors affiliated with institutions) to conduct research leading to a paper's publication (Katz and Martin, 1997; Mêgnigbêto, 2013). Another evidence for collaborative activities from different organisations also presents by joint publications (Van Raan, 1998). The publication is a home for scientific knowledge where research and academic activities are structurally well documented. Scholarly outputs help to trace the performance of researchers and even institutions in a scientific framework. Nevertheless, to point out that not all collaboration leads to co-authored publications due to researchers' interest to publish independently, although they have conducted research together.

Analysing the co-authored publication's network through bibliometric methods improve to capture precisely the main aspects of collaborative works (Glanzel, Schubert and Czerwon, 1999). Bibliometric analysis can explore many determinants and examine the collaboration network more extensively than other approaches (Melin, 2000). Besides, co-authored papers offer more approaches to obtain data (Melin and Persson, 1996). Mêgnigbêto (2013) explained other advantages of using co-authored papers to analyse collaboration: (a) relatively stable

from economic and political shocks, (b) significantly proven as academic collaboration because co-authored publications has been manifest from some part of collaborative research activities; (c) doable since collaboration data are available through many credible sources, such as the Web of Science (WoS), Google Scholar, PubMed, Scopus; (d) cost and time efficiency in data collection compared to primary surveys; (e) enormous parameters can be used as a sample of study and; (f) suitable for various statistical tool analyses.

Furthermore, co-authored papers can represent an attractive interaction regarding information attached to the co-publications, and it demonstrated in diverse forms related to analytical approach selection (Van Raan, 1998). For instance, a co-authored paper can identify connections between the scholars as authors, between institutions where the author works, and between spatial locations (cities, provinces, countries, and regions), formed into co-authored structure publications networks. The co-authored publications can measure the interdependency among the actors within the network structure. It reflects a joint work among a paper's authors consisting of elaborating ideas, managing tasks and time, writing up, tailoring between chapters, editing and submitting, and revising the paper.

The number of co-authored articles has grown remarkably over the last 100 years. The co-authored article was initially published in 1665 and has been a baseline for following academic collaborative works (Luukkonen, Persson and Gunnar, 1992). In the early 1900s, co-authored publications were calculated not more than 10% from total publications at that moment, while they rose beyond 50% in the rest of the 20th century (Wagner-Döbler, 2001). Gazni and Didegah (2011) also found co-authored papers comprised 66% of the total publications in 22 various research areas. These may be seen obviously among European regions where they have promoted collaboration to integrate regions and bridge the knowledge during the 1970s-1980s

(Luukkonen *et al.*, 1993; Luukkonen and Lemola, 1998). The number of authors in an article varied based on the science subject. The number of authors for one article is averagely from 2.83 (mathematics) to 9.41 (physics), with a total of 16 research areas that have been assessed (Abt, 2007).

2.2.2 Concept of Region

Defining a region is essential for particular purposes. Policymakers demand an appropriate region concept to ensure the policy has significant impacts and achieves outreach and sustainability. Having a suitable concept is beneficial to measure the performance and develop further plans precisely. Meanwhile, a mitigation strategy for potential disasters and diseases also requires a firm concept of the region because it requires accurate knowledge of the impacted area. Identifying the region is associated with spatial boundaries and political aspects essential to identify assets, economy, investments and trade, power, and security. Understanding a region may reduce the risk of a region's misconceptions as a group of countries and as a sub-national.

A region physically forms by the restricted nations interconnected through spatial interactions, like cooperation and dependency (Nye, 1971). A place as a part of the global world can be counted as a region when it links to other spaces through geographical location and multi-sector cooperation (Paasi, 1986). A region consists of spaces connected by spatial proximity or interactions formed by a particular character as physical identity and non-physical identity, like the unification of policy or institutional regulations.

The definition of regions has continued to develop. Interaction among the members has attached particular cooperation that distinguishes it from other space (Smith, 2004). For

example, the European region developed from economic cooperation and succeeded in presenting its region's characters. Once it has been recognised as a spatial area's identity, the region will exist (Van Langenhove, 2013).

The determinant factors have been crucial in defining a region. Every space has been established differently, and this makes every region unique (Chan, 1990). For instance, Southeast Asia has grown as a region due to social factors; they are interconnecting countries, represented through an institutional framework (Liu and Regnier, 2003). Across Europe and the Asia Pacific, economic cooperation, and mutual dependency between industry and trading countries have signalled the main drivers in regions' construction process (Chan, 1990; Liu and Regnier, 2003). The entrepreneurial spirit underlies cooperation among nations, followed by government agreements to formally arrange cooperation through political and institutional arrangements (Haas, 1979). Hence, motivation and underlying factors will determine region, intensity, and sustainability cooperation among members within the region.

Understanding the concept of a region is sometimes challenging. A region is not a nation, but it represents a symbol or institution (such as congress, flag, law) that generally belongs to a nation (Van Langenhove, 2013). A region contains dimensions of material and is symbolic, like physical and political elements (Katzenstein, 2015). It can be said that there are at least five key elements contributing to the development process of a region like: a) spatial characters as territory; b) interaction among the actors within the region which elaborate into a social system; c) cooperation in multiple sectors that formed a particular network; d) a society to promote values from the shared goals of the actors and; e) a symbol or identity that has been accepted globally.

A region is tied to the period in which activities and substances in the region are dynamics and will never be the same over time (Wishart, 2004). It means a group of spaces recognised as a region based on a specific period. For example, Eastern Europe from 1945 to 1990 comprised eight countries which had been strongly influenced by Soviet Union power. Later, it separated into four regions: Central Europe, Baltic Europe, Balkan Europe, and the Eastern Borderlands (Dingsdale, 1999). 10 country members from Central Europe and the Eastern Borderlands joined the EU in 2004 and 2007, shifting to the leading and more prominent economies (World Bank, 2008). They currently are a subdivision of the EU in industrial, political, legal, economic, and socio-cultural integration (OECD Statistics, 2001).

The extensive literature has previously nominated regions for countries' conglomerations (EU, ASEAN, African Union, Arab League, Caribbean Community, East African Community, Inner Mongolia). These groups were formed by shared and mutual goals of politics, economy, social-cultural aspects, and security. The cooperation has conveyed further collaborations, such as knowledge and technology transfer, labour mobility, and integrated transportation, which bring development and competitive advantages for the European region.

2.2.3 Global South (GS) Countries and Global North (GN) Countries

The terms of GN and GS have been popular in academic publications, international discourses, and policy analysis since the Third World became less popular after the Cold War (Moore, 2017). The South-North concept was initially documented in 1996 through a bibliographic study (Pagel *et al.*, 2014; Eriksen, 2016). In 2004, South and North's terms were stated in 19 publications and 1204 publications in 2013 (Pagel *et al.*, 2014; Eriksen, 2016). These publications were authored by scholars from the United States, the United Kingdom, Canada, Australia, and Germany. It indicates the terms of GN countries and GS countries mostly

promotes by high-income countries geographically positioned in the North than low-income countries located in the South.

Distinguishing global communities into North and South is practically challenging. The indicators to differentiate the identities of the North and the South are continuously changing. The Brandt line introduced in the 1980s geographically divided the world into North and South. North referred to high-income countries in the Northern Hemisphere and included Australia and New Zealand as exceptions. The South were low-income countries in the Southern Hemisphere (RGS, 2016). By this time, this group separation was too facile, notably, as it neglected some countries that have incomes beyond the average world GDP per capita, like Argentina, Singapore, and Malaysia but were included as GS countries. In another case, certain countries may be under control by the advanced-economy countries but geographically positioned among developed-economy countries, and vice versa. By economic performance, the country qualified as GS but spatially locates in the North; otherwise, it is economically as GN but geographically lies in the GS (Moore, 2017). Understanding of the concept of GS and GN will be more contextual than generalisation of definition. In the meantime, there are several approaches to define GN and GS seen from historical contexts, politics, economy and development performance, geography, and migration flow.

North and South recognise as two opposite characters. Identification of GN and GS is represented as two contrasting conditions of domination and inferior, independency and dependency, innovative and uninventive, developed and developing (Camaroff and Camaroff, 2012). GN is assumed to include countries with high economic levels with well-established political systems, steady and mature security, and central for global cooperation. Meanwhile, the GS is associated with countries with low levels of economy, vulnerable in politics and

security, needy for health and education services, low standards of living, receiving support from GN countries, and mostly positioned in the periphery of the international cooperation networks (Karlsson, 2002; Eriksen, 2016). The United Nations Development Programme (UNDP) distinguishes South and North through the Human Development Index (HDI). It found that 64 countries with greater HDI index mostly situate in the North, and the rest of the countries (133) assigned to the South.

The concept of North and South does not always resemble economy and spatial relations. GN-GS relation may reflect historical experience in colonialism (Camaroff and Camaroff, 2012), as GN countries recognise as the mother colony and GS countries are the GN colonies (Moore, 2017). Over time, the terminology of GS countries is useful to capture South-South relations. The South-South relation initially started through the Asia–Africa conference in Bandung, Indonesia, in 1955 as a political movement from countries in the GS to articulate their voices and promote their independence from GN sovereignty (Rigg, 2016). They argued colonialism has made their economy underdeveloped since most of their resources have been exploited by GN countries. Rigg (2016) also emphasised that the collectivist view drives cooperation between countries in the GS.

South-South cooperation was promoted through the Dependencia view in the 1960s. The aims of South-South cooperation are: accelerating their economy and development, improving education and health services, implementing security in the region, and strengthening voices from the GS in the global community (Moore, 2017). However, it has been challenging to develop a cooperation scheme for South-South cooperation without colonialism influence. As GS countries have a greater dependency on the GN in trade, investment, and technology,

existing GS cooperation schemes are strongly influenced by patron-client relations and imperialism's nuances.

Similar to the historical approach, the GS may represent a group of countries that have not benefited from globalisation. Unfortunately, with the limited internal capacity to utilise resources, countries from the GS could not generate advantages from globalisation (Pagel *et al.*, 2014). GS countries internally encounter national issues, such as low quality of education and health system, immature political systems, weak regulation and poor law enforcement, poor leadership and weak institutional capacity, and insufficient budgets to finance development. Budget constraint is a common challenge in most countries in the GS. In the meantime, having an adequate budget is crucially fundamental to support priority sectors in national development, like primary infrastructures (transportation, ICT, energy), education and health, research and development, and primary industries related to existing resources.

Interestingly, the UN has included Singapore as part of GS (United Nations, 2008). The UN has selected Singapore as a key country from ASEAN, similar to China (East Asia), India (South Asia), Mexico (South America), and South Africa (Southern Africa). From the economic perspective, Singapore has greater economic capacity than the other four countries, meanwhile spatially, Singapore is located in the South and strategically influences neighbouring countries in Southeast Asia. Through geographical considerations, Singapore can identify with a North qualification but lies in the South part.

2.2.4 IRC Experiences between GS Countries and GN Countries

Collaborative research between the GS and GN manifests in the form of diverse relations. Many scholars have identified GN–GS partnerships as a donor-recipient relationship (Johnson and Wilson, 2006). GN countries can be viewed as 'givers' because of their research excellence and education performance (Binka, 2005). For instance, North America has been the source of half of the world research and development (Huggins, Demirbag and Ratcheva, 2007), while the UK and the US have determined the global international education system and research culture due to their outstanding performance in these aspects (Crossley, 2014) and the European countries have sustained production of innovation in technology (Crescenzi, Rodríguez-Pose and Storper, 2007).

GN-GS collaboration is associated with the terminology as opposite characteristics, such as Indigenous-Colonial, Western-Eastern, Western-African, European-Asian, and Northern-Southern (Connell *et al.*, 2017). In the meantime, collaborative research has been more dominant in the documentation of North-South cooperation since the post-colonial era. Over time, scientific collaboration between the GN and GS has shifted gradually from 'scientific colonialism' into 'mosquito research practice' (Edejer, 1999). Mosquito research practice describes through the following illustration. GN countries were conducting collaboration with GS countries by collecting data (samples) from GS countries as the research object (location), and then returned to their home country to undertake further treatment (laboratory, simulation, analysis); finally, the findings resulted in a paper publication (Boshoff, 2009). Therefore, the country partners (GS countries) who have provided data and supported research activities is potentially neglected and received minimum benefits from research collaboration (Binka, 2005). The GS's minimal advantages are related to knowledge transfer, capacity building, and the learning process ((Edejer, 1999; Knobel, Simões and De, 2013; Collyer, 2016). These

potential advantages are primarily required to leverage research capacity development in GS countries. As a result, GS countries' research capacity has not improved much in the last three decades.

Limitations in academic resources and research capacity have motivated countries from the GS to pursue IRC with GN countries. Research activities estimated from international publications in GS countries remain low due to a lack of knowledge resources and research facilities (Knobel, Simões and De, 2013). Insufficient budget allocations for research, political decisions, and low-quality human resources are the common causes GS countries are left behind to GN countries (Binka, 2005). Concerning improving knowledge capacity, GS countries perceive GN countries to have an abundance of research resources, high-quality academic knowledge, advanced technology, and innovation (Bradley, 2014). All of these have been strengths for GN countries in collaboration with GS countries, while, on the other side, have motivated countries from the GS undertaking IRC with GN countries.

On the other hand, GN countries have seen that conducting IRC with GS countries is promising. Research partnerships with countries that have different characters compared to GN countries aim to enlarge their market in the emerging economy, implementing affordable research with low-cost materials reduces costs for distribution, and also gains different knowledge that does not exist in GN countries (Taylor *et al.*, 2007). Several parts of the GS have encountered difficulties in mitigating particular diseases, natural disasters, energy security, and food security. These situations may be seen differently for GN countries. Several development issues in the GS countries can be a pathway to create new knowledge and generate innovation through intensive collaborative research. Some collaborations with GS countries have resulted in medicine and vaccines for tropical diseases, early warning equipment to

mitigate disasters, innovation in food processing and food products, and new technology for sustainable energy (Hall, 2002; Jentsch and Pilley, 2003; Tierney *et al.*, 2013).

The IRC implementation between GN and GS countries identifies various forms of cooperation regarding geographical location, such as the economy and knowledge flow, industry and knowledge transfer, geographical proximity, and historical ties. Industrial research collaboration between the North and South has shifted from science (nuclear, biosciences, medical) to natural sciences (earth, geology and natural resources, space and atmospheric, and marine) and also the ICT sector (Georghiou, 1998). GN countries (US, Canada, UK, most European countries, Japan, Australia–New Zealand) are represented as primary sources for global knowledge and global innovation. In contrast, GS countries (Latin America, South Asia, East Asia, Southeast Asia) are the potential market for the industrial expansion of GN countries. Simultaneously, a pattern of IRC with colonial ties has been presented between North America and South America, South Asia and EU countries, Latin America and European countries, and European countries–Japan and Southeast Asia. However, the relationship between academia and the economy (international trade and FDI) also represents a similar pattern between academia and historical ties. IRC seems to grow more intensive due to geographical proximity, such as that experienced between Canada and the US, New Zealand, Australia, and European countries.

However, mutual collaboration has been a crucial issue in cooperation between GN and GS countries. Many studies have discussed some methods to promote mutual partnerships and equal collaborative research roles (Gaillard, 1994; Johnson and Wilson, 2006; Biraimah, 2016). Unbalanced knowledge production dimensions between GN countries and GS countries for

productive resources, authority, knowledge, and innovation capacity and outreach to the global world underlie the initiative (Johnson and Wilson, 2006).

Collaboration ideally can bring equal advantages for both sides. In order to promote mutual research partnership between GN-GS, collaboration should be socially oriented and less market-driven, focusing on academic and humanitarian purposes, elaborating capacity building for GS countries (Chetwood, Ladep and Taylor-Robinson, 2015). Four board principles potentially implement over 1) having mutual trust; 2) respect national ownership and promote national resources; 3) bridging from academic findings to policy practice implementation and; 2) strengthening domestic research capacity (Jentsch and Pilley, 2003; Johnson and Wilson, 2006; Koehn, 2014). These concepts should be acknowledged by policy makers (political decisions) and scholars to lessen the influence of the colonial research partnership scheme in developing countries (Costello and Zumla, 2000).

In order to support the implementation of mutual collaboration, practitioners need to be involved both in the engagement process and during IRC activities to design suitable collaboration schemes for both sides. This strategy can be applied primarily in GS countries' key sectors, like education, public health, energy, public service, disaster management, and infrastructure (Johnson and Wilson, 2006). These fundamental sectors directly influence human resource quality and research capacity development, which are foundations for creating knowledge and generating innovation internally. Furthermore, the following strategy can foster communication between scholars from GN and GS countries via instruments like technical assistance and expertise, training and short courses, and joint seminar or conference post-research activities. Besides, these instruments of collaboration can advocate voices from GS in IRC.

Understanding unequal conditions of academic performance and research capacity between the GN and GS, Gaillard (1994) suggests research priorities between the GN and GS should not be identical but complement each other. Finding the cutting-edge of research seems able to overcome different interests. For example, if GS countries focus their research on agriculture as endowment resources, the GN may help advance agro-industry through collaborative research with GS countries. Furthermore, in order to reduce the research capacity gap, several approaches to providing support, like giving technical assistance to GS countries before undertaking research, particularly for basic natural science; inviting local researchers from GS countries to join overseas training to obtain international experiences; carrying out institution-building and institution training arrangements. These aim to improve research capacity and capability in GS countries before conducting collaborative research. Gaillard also gave several programmes as example of GN–GS research partnerships which have been initiated since 1980, for instance: cooperative research from Canada for capacity empowerment in developing countries; the Swedish Agency for Research Cooperation with Developing Countries (SREC); CRSPS and PSTC by US-Aid; research grants from the US; and science and technology development from the European Community.

The disparity has influenced the unbalanced participation in knowledge production in knowledge and research capacities between GN and GS countries. The disparity between them is triggered by several conditions such as: *first*, and GS countries have found difficulty in providing research funding, as their research funding has not exceeded 10% of the total amount of the average research budget in GN countries (Edejer, 1999). Therefore, most of the IRC initiatives promote by GN countries. As a result, interests in IRC are dominated by GN countries' perspective instead of GS countries' needs. *Second*, transnational labour mobility

between GN countries (European countries and the UK, US and Canada, Australia and New Zealand) has contributed to fostering knowledge flows and accumulating better knowledge (Collyer, 2016). *Third*, the way of thinking on the research approach. Scholars from GS countries usually work on case studies while GN countries undertake research aiming for generalisation as this approach seems useful for acceptance in global sciences (Connell *et al.*, 2017). In other words, by generalising the approach from their findings, publications from GN countries tend to be more cited than from GS countries.

Fourth, sufficient resources have impacted higher performance in academic knowledge, research activities, and innovation generation. As world-class academic knowledge producers, GN countries have strong characteristics and endowment resources related to scientific activities, such as the high profile of human resources with an immense number of Ph.D. holders, political support from the government, adequate budget allocation for research and development, and well-established institutions (Connell *et al.*, 2017). Another element to implement a conducive academic and research environment is the substantial cooperation between universities or research centres with publishers to help manage their publications, promoting their findings in many global academic forums. *Fifth*, GN countries have been advanced in managing research resources by integrating various background research subjects from many research activities. The strategy implement through developing a centre or research group to promote intra-regional collaboration and interregional collaboration (Gusmão, 2001; Barré *et al.*, 2013). A research group and an integrated research body strengthen cooperation between countries and bridge the resource gap between them (particularly for funding, technical assistance, equipment, and technology). Therefore, it has fostered knowledge flows between the countries (Cappelli and Montobbio, 2014)

In the meantime, South-South cooperation also rises recently. For example, China and India have been the magnet for IRC between Global South countries since they are prosperous in developing their research capacity, particularly for IT and communication, physics, chemistry, bioscience, astronomy, and astrophysics (Arunachalam and Viswanathan, 2008). Simultaneously, the remarkable growth of their industries (similarly with their excellence in research subjects) has been indicators that these countries have successfully generated advantages from IRC (Rosseel and Corte, 2009).

However, apart from South-South collaboration, a new intra-Asia collaboration cluster has been formed in the last decade by involving China, Singapore, Malaysia, Japan, South Korea, Taiwan, and Hong Kong as the main partners (Board, 2016). Some experts presume there is a similarity between EU strategies and policy strategies to promote IRC in Asia. The EU admits as a prominent example of how intra-regional collaboration is well developed by strengthening fundamental elements for IRC such as accelerating an integrated infrastructure development for transportation and communication sectors; launching a collaborative research board that accommodated preferences from the members; implementing industry and trade integration; and economic and institutional unification. A similar strategy has been applied in China at the sub-national level and the African Union.

2.2.5 Summary

Among several concepts and definitions of Global South (GS), some limitations describe groups of countries by the actual characteristics of every member included in the group. *First*, the separation of South and North is not literally by geographical contexts only (in the South and North) and other factors such as economy, development, history, political power, and relation. This makes segregation to have a tendency to be edgeless and limited to capture the

world's socio-economic conditions (Duck, 2016). Splitting South and North cannot be conducted as black and white since the factors between them are interlocked. Countries with North characteristics may locate in the South, and vice versa. *Second*, geopolitics has been a factor in the use of GS terms. The GS definition has not been fixed and rigid concerning geopolitics dynamics. *Third*, the concept of GS seems ambiguous to streamline a wide range of nations with differing characteristics toward a single classification.

Another implication from this North-South concept of boundary is how the concept could be a wall separating two different parts of the world. This may bring obstacles for disadvantaged groups to have equal access and power for capacity building and development. Segregation between South and North countries will negatively affect cooperation. Meanwhile, the GS term's application reflects how this term is accepted to illustrate world structure in the nuances of politics, power relations, socio-economic and historical background. However, the most crucial factor is that GS and GN terms' application will follow the context and cannot be locked as a rigid term. It seems that the term GS will continuously grow, and the members will shift over time simultaneously with developments in geopolitics and geo-economics.

However, participating in the global knowledge production network will be challenging for GS countries since GN countries initiated the most well-established collaboration schemes. In the meantime, unequal research capacity between GN and GS has triggered GS dependency on the GN. Thus participation in knowledge production is dominated by GN countries. Therefore, efforts to promote mutual collaboration are practically difficult to separate from the stereotypes of GN–GS relations, for instance, colonial ties, donor-recipient relationship, and First World–Third World, since academic evidence in expressing interest and views from countries in the GS are limited in terms of documentation. It can be said this is in line with little discussion of

the scholarly outputs of countries from the GS, including a discussion of IRC between the GN and GS.

2.3 Determinant Factors of International Research Collaboration

2.3.1 Motivation in Undertaking IRC

Research collaboration has been essential in academic science development for the last few decades. IRC is part of internationalisation for researchers, institutions, and knowledge (Melin and Persson, 1996; Olenchnicka, Ploszaj and Celinska-Janowicz, 2019). Internationalisation for academics is crucial as global scholars' recognition because this process involves simultaneous stages like reviewing, assessment, followed by revision and restructuring of joint research in the form of papers until the resulting final outputs meet academic requirements. In short, IRC is demanded international acknowledgment in the global scientific community.

The collaboration between researchers from different countries has been motivated by various factors, ranging from personal reasons to be more institutional interest. At a personal level, collaboration through co-authored papers potentially promotes academics' careers in scientific communities (Olenchnicka, Ploszaj and Celinska-Janowicz, 2019). Publications with more co-authors from various countries tend to be potentially more cited than publications with authors from one country (Martin *et al.*, 1990) and also have the most rapid increase in citations from researchers (Cozzens *et al.*, 2011). The more country addresses (academic institutional addresses from different countries) in a paper presumes, the more critical the global science (Nagpaul, 2003). The co-authored paper draws more attention from scholars, policymakers, and practitioners than a single-authored paper since it has combined multiple expertise ((Foley and Della Sala, 2014). Undertaking international collaboration also leverages article quality, leading to being cited by the following studies (Katzenstein, 2015). The more an article is cited,

the greater its impact on knowledge creation (Jaffe and Trajtenberg, 1999; Ding, 2011; Gazni and Didegah, 2011). The number of citations per article is crucial in determining an individual's performance and the institution of scientific works.

Collaborative research also aims to increase institutions' performance in global competition (Knobel, Simões and De, 2013; Crossley, 2014). The number of international publications and citations has been used as one indicator of universities and research centres' performance by global indexing institutions, such as the Times Higher Education, Top Universities, QS World University Ranking, and The Complete University Guide. Knobel et al. (2013) explained that conducting overseas collaborative research can increase international publications and citations to increase university ranking. Meanwhile, global university ranking also affects academics' probability for universities to be selected as potential research partners (Crossley, 2014). A higher university global ranking position is associated with better education systems, research activities, and academic staff. Reputable universities can attract scholars with high academic publications reputations (Chetwood, Ladep and Taylor-Robinson, 2015). In other words, prominent universities will continuously maintain their reputation by selecting and receiving high-quality scholars as part of their academic staff. The two situations above demonstrate that collaboration and reputation are reciprocally correlated. Collaborative research can generate higher academic output performance (publications) and lead to a better institutional reputation. Meanwhile, international reputation (e.g., global ranking) draws interest from potential collaborative partners to undertake IRC. In short, collaboration is a channel to increase knowledge capacity and international recognition.

Moreover, IRC has the benefit of improving internal capacity. collaboration helps to transfer operational knowledge and necessary knowledge to improve the internal capacity of

individuals, institutions, and nations (Bergé, Wanzenböck and Scherngell, 2017). Having sufficient internal capacity is essential to develop a robust baseline for further collaborations since every collaborator should contribute their competencies mutually (Jeffery, 2013). Collaborative research provides more opportunities and widens international academic networks (Johnson and Wilson, 2006). Therefore, this may be useful to generate broader cooperation beyond that of academic collaboration.

Improvement of ICT development has stimulated the growth of IRC. Innovation in the ICT sector successfully reduces the constraints against collaborating internationally (Chetwood, Ladep and Taylor-Robinson, 2015). Advanced development of technology helps to accelerate communication and eases knowledge transfer, which is conducive for undertaking IRC (Montobbio, Primi and Sterzi, 2015). ICT development can reduce travel costs by substituting face-to-face meetings with indirect communications, for example, via the internet and telephone, video calls, and video conferences (Knobel, Simões and De, 2013; Lengyel *et al.*, 2015). In the meantime, massive development in the transportation sector has made many places better interconnected. It has been strengthened by innovation in modes of transport leading to cost and time efficiency in travel, for example, more affordable tickets with shorter travel times. These situations have encouraged people to travel globally, and ICT provides a better way to communicate across nations. In other words, ICT and infrastructure developments have made people better well interconnected both via direct meetings (offline) and indirect meetings (online).

Furthermore, IRC has been perceived as a promising approach to address internal limitations in knowledge production. Collaborative research helps to bridge between countries with abundant resources and limited resources. These resources are generally related to funding,

human capital, facilities, materials, and technologies crucial to support research activities (Binka, 2005; Knobel, Simões and De, 2013; Biraimah, 2016). Applying for funding regarding research resources is the most apparent motivation in undertaking IRC ((Katz and Martin, 1997), especially in the relation between low-income countries and high-income countries. Low-income countries generally encounter budget limitations as the primary issue to conduct research (Li, Liao and Yen, 2013). Also, IRC facilitates the sharing of data, materials, and equipment. These can be rare and expensive for specific countries, while in other countries, they are available and affordable to access ((Katz and Martin, 1997; Vayrynen, 1998; Practice, 2001; Rusly, Yih-Tong Sun and L. Corner, 2014). By undertaking IRC may increase the researcher's specialisastion (Katz and Martin, 1997). Division of labour is potentially implemented in a collaborative framework when every collaborative partner has contributed through their specialty. This approach helps to make the research conducted more efficient and results in impact (advantages). Therefore, recognising underlying factors is beneficial to select the type of collaboration that suits the collaborator's character and capacity. In the end, it will determine the quality and sustainability of IRC.

2.3.2 Determinants Factors of IRC

Besides motivation, collaborative research comprises complex processes: formal and informal channels, individual and institutional approaches. In certain situations, specific purposes drive research collaboration. Academic collaboration undertakes preliminary cooperation to make a baseline for further cooperation such as investment and trade; casual diplomacy for bilateral and multilateral cooperation; and addressing local and global issues like health, environment, migration, and economic crisis. In the meantime, there are other dimensions as underlying factors influencing the degree of closeness or proximity between countries. These elements are known as a separation between countries, such as geographical, cultural, economic ties,

historical background, and political interest (Jarneving, 2010). The characteristics of a country regarding a county's size have contributed to developing separation elements. The elements above are presumed to determine IRC in terms of the likelihood to collaborate, the number of collaborative partners, the intensity, quality, and sustainability of cooperation (Boardman, 2009; Ostergaard, 2009; Koehn, 2014).

2.3.2.1. Size of Country

Melin & Persson (1996) revealed that an institution's size determines collaboration similarly at local, national, and international levels. This size is assumed to negatively relate to efforts to undertake IRC (Melin and Persson, 1996, 1998; Melin, 1999). Due to insufficient internal research capacity, small countries tend to seek collaborative partners beyond their countries. For example, countries like Singapore and Iceland engage more with international than national research collaboration. In contrast, large countries with sufficient resources will have more excellent national (within the country) research collaboration instead of international collaboration. The United States (US) as possessing the most extensive size in academic resources in the world demonstrates much greater national collaboration. Furthermore, the relationship between academic size and the tendency to collaborate internationally also influences its collaboration structure regarding total publications.

The volume of research collaboration of a country is proportional to the total number of collaborative publications, including papers co-authored by national and international co-authors. The share of collaboration is relevant to the degree of science independence to avoid isolation from global science communities (Vieira and Gomes, 2009). However, it is not easy to define an ideal structure of research collaboration for a country since its characteristic has influenced it. For example, a large country may have a more significant proportion of national collaboration, while a small country tends to seek collaborative partners from abroad as a

source of knowledge. Unfortunately, discussion about the relationship between collaboration and country independence is limited in knowledge production literature. Therefore, it is critical to ensure that IRC can generate advantages for science development and economic growth.

2.3.2.2. Geographical Proximities

Geographical factors are fundamental in influencing the process of communication and collaborative research. The most prominent element in geographical factors is a distance, which closely associates with geographical proximity. This proximity has been a fundamental dimension determining the probability of collaborating in knowledge production literature, particularly in communication construction between collaborators (Boschma, 2005). Geographical proximity increases the possibility of individuals to meet, communicate, and coordinate; otherwise, distance inhibits communication and connectivity (Howells, 2002; Wanzenböck, Scherngell and Lata, 2015), either through an online network or offline network (Ellison, Steinfield and Lampe, 2006; Scellato *et al.*, 2010; Lengyel and Leydesdorff, 2015). Direct meetings are beneficial to ease the better sharing of information and transfer knowledge (Abramovsky and Simpson, 2011). Individuals naturally will seek external knowledge close to where they reside. For example, collaborative research between members of the European Union (EU) is more robust than research collaboration between EU members and non-EU (Noni, Ganzaroli and Orsi, 2017). In other words, countries with geographical proximity imply stronger cooperation. Researchers who reside close to each other will have more intensive communication conducive to strong collaboration.

Another example can be seen from patent citations that geographical proximity has negatively influenced knowledge flows (Quatraro and Usai, 2016). Patent citations are sensitive to distance, which has impacted knowledge spillover that tends to be local (Jaffe and Trajtenberg, 1999; Ribeiro *et al.*, 2014). Local spillover is in line with the concept of knowledge flows,

which is very sensitive to distance and time dimensions regarding the transfer process (Gertler and Levitte, 2005; Caiazza, Richardson and Audretsch, 2015).

On the other hand, geographical proximity seems to be fuzzy on collaboration when collaboration undertakes through well-established relations. The relation may occur in long-term joint research, alumni or graduate relationships, and historical relations (Ponds, van Oort and Frenken, 2007b; Abramovsky and Simpson, 2011). The effect of geographical proximity through these relations may differ from conventional channels like migration, FDI, and trade.

From a geographical perspective, IRC may present a particular pattern concerning the authors' location. Historically, authors from big cities have majorly contributed to IRC, which is home to most universities with international recognition (Maisonobe *et al.*, 2016). Major prominent universities with excellent global science performance tend to have greater participation in IRC (Schubert and Glanzel, 2006) World-class universities generally establish from a long process of academic activities and outstanding research quality.

Nevertheless, geographical proximity cannot be seen as a single factor determining IRC. The evidence demonstrating a relation between co-location and higher engagement between collaborators is limited in the collaborative research literature (Abramovsky and Simpson, 2011). Neighboring researchers do not always collaborate more intensive than the researcher who resides in the distance. Although universities and industry are physically close to each other, they may not have much collaborative research. They perhaps are not well inter-connected through similar interests in a particular subject or sector. For instance, in many developing countries, foreign-owned industries mostly reside industrial estates but have less collaboration with local universities (Moeliodihardjo *et al.*, 2012)). There are other factors in

addition to geographical factors that influence the probability of collaborating internationally, which in certain conditions are associated with the motivations to conduct IRC, such as performance in academia and research, the suitability of the research subject, and potential gains from the collaboration.

2.3.2.3. Historical Ties and Language as Social Proximities

Social proximity affects how individual relations support research collaboration. Fellowship, relatedness, and involvement at the personal stage commonly represent social attachment (Boschma, 2005). Compared with organisational proximity (character, strength, ethics) at the macro scale, social proximity occurs at the micro-level.

Social interaction is driven by trust. Trust is vital for individuals to build communication and collaboration with other individuals (Broekel and Boschma, 2012). In the meantime, the presence of trust in a relationship reduces communication constraints between individuals. The degree of trust has influenced knowledge flows among collaborators (Agrawal, Kapur and Mchale, 2008). Besides, trust helps to minimise unbalanced participation between the collaborators (like a free-rider) and reduces the risk of unpresented information (Ter Wal and Boschma, 2009). It means a trust-based relation is fundamental to promote sustainable collaboration and maximum advantages from its collaboration.

Social proximities identify using historical relations, reflecting how the individuals connected before the event. For instance, civilisations that have occurred over a long period have affected social bond development between collaborative partners because of their similar experiences, intuitions, ideology, and collective goals.

Another example is colonialism, which creates a patron-client relationship between the imperialist and formerly colonised countries (colony). At the micro-level, individuals have connected caused by similar experiences in education (graduated from the same institution), where they came originally from one hometown, or work in the same field (subject/sector) and have a specific experience of involvement for a certain period (supervisor and student relation, the boss and staff, the sponsor/funded and receiver). These situations have generated feelings of friendship and built a sense of belonging to the community, increasing the social proximity between collaborators.

Another reflection of social proximity in practice is the similarity in culture and language. These similarities developed historically through a long continuous process as manifested in individual interactions. In certain situations, language and culture similarity is interchangeable. In other words, culture determines the language and vice versa. Countries with cultural similarities usually have a similar spoken language. Language and cultural similarity are determined by three factors: geographical proximity, migration, and historical ties. Neighboring countries tend to have a similar language, like in Southeast Asia (between Indonesia, Malaysia, Singapore, and Brunei Darussalam), East Asia (Taiwan, China, Hong Kong), and Scandinavian countries. Countries with high migration flow tend to have similarities in spoken language and culture (Montobbio and Sterzi, 2013). Also, colonial ties may force language and culture similarity between the mother colony and their colonies, such as Spain, Argentina, Cuba, and Mexico, and between French and Southern African countries (Adams, 2012). Language or cultural similarity is more likely to ease communication and cooperation between individuals.

Higher social proximity triggers high dependency on collaboration. Very close social proximity may impact excessive devotion leading to high dependency in cooperation (Boschma, 2005). Meanwhile, this is potentially disadvantageous in creating new knowledge and innovation due to impediments in the growth of creativity, seeking other opportunities, and utilising resources for generating advantages.

2.3.2.4. Organisational Proximities

Organisational proximity derives from the situation that a researcher is attached to a national system as a framework to manage their activities. In other words, researchers should deal with and be familiar with the organisational system where they reside. Organisational proximity defines"…..as the extent to which relations are shared in organisational arrangement, either within or between organizations" (Boschma, 2005, p. 65). It expresses the degree of independence between members of an organisation that distinguishes between autonomous and dominated (controlled) within the system. In organisational analysis, some members may have a high degree of freedom, whereas the rest are bound with limited independence.

Organisational proximity has been an essential determinant in IRC. At the country-level analysis, organisational proximity may be expressed by the similarity of characteristics in the national system (policies, regulations, and incentives), political interests, and active participation as a member in an international organisation (Broekel and Boschma, 2012). The similarity of characteristics between organisations may reduce the conflicts and issues between them as constraints of collaboration. This brings advantages for IRC, particularly as it would lessen the efforts to develop collaboration, which means savings in cost and time. Nevertheless, there is a risk with a higher degree organisation, which may trigger a rigid framework for cooperation that is contra-productive for sustainable collaboration (Boschma, 2005).

However, organisational proximity may foster collaborative research activity if competition between members is less robust than active participation to achieve common goals. Formal agreements and a vital institution that manages cooperation between the members may strengthen collaboration. Some examples are presented as follows. Local government facilitates collaboration between local universities and industries at the national level crystallised into local economy cooperation for innovation (Goddard, Vallance and Puukka, 2011; Benneworth *et al.*, 2015). At the regional level, the presence of the EU has enhanced cooperation and collaboration between the members, particularly in the active role of European Innovation Regions as an agency to grow innovation and foster research collaboration within the EU (Wanzenböck, Scherngell and Lata, 2015; Quatraro and Usai, 2016).

2.3.2.5. Country's Openness

The degree of national openness determines the ability to acquire external knowledge since tacit knowledge is embodied within the individual. Openess means how the nation supporting the process of mobility and exchange (both physical and non-physical). National openness determines knowledge flow through various channels: people-to-people mobility, imported technology and machineries via international trade framework, and foreign direct investment with higher opportunity to accelerate knowledge acquirement using international expertise, labour and equipment in development process of new plants or manufacture. The degree of national openness determines the ability to acquire external knowledge since tacit knowledge is embodied within the individual.

For instance, regional integration between EU countries has been easing transnational labour mobility and impacting on fostering knowledge flows (Collyer, 2016). Less restriction on

migration increases the frequency people to meet, to discuss and to conduct some experiments. Knowledge will exchange faster, greater and more sustain. In contrast, similar situation might rarely occur in GS countries where expertise mobility and labour migration are more rigid than GN countries due to the administration process, legal framework, and entry-exit permit. The regional integration process seems to be undertaken slowly, which brings effects on low mobility of capital, goods, and human resources between countries.

2.3.3 Summary

Several factors have been explained above that are practically crucial in IRC implementation. These factors have determined collaboration intensity between regions in Central Europe and Scandinavia (Schubert and Glanzel, 2006). Studies were undertaken in the top five global academic countries (France, Germany, Japan, UK, USA) and it was found that similarities of history, culture, and language are significant in influencing collaboration (Zitt, Bassecoulard and Okubo, 2000).

Undertaking IRC has been motivated by various underlying factors related to country characteristics. Every country may see IRC from a different perspective. For example, GS countries perceive IRC is promising to address some limitations regarding research activities, like seeking external funding, sharing research materials and equipment, and accessing technical assistance. Meanwhile, GN countries employ IRC to acquire external knowledge that cannot be generated internally to produce new knowledge and grow innovation. Besides country characteristics, there are some proximities as a manifestation of countries' separation. Among the three main proximities, geographical proximity is the most prominent factor studied in knowledge production literature. Motivations and proximities are known as IRC's determinant factors since elaboration between them simultaneously influences IRC's

likelihood. The effect of determinant factors on IRC may differ between countries due to other non-presented factors that indirectly affect IRC.

2.3.4 Hypothesis Development

H1. *Academic publication has a significantly negative relationship with international collaborative research output*. Scholarly outputs represent the size of nation that negatively determines propensity to undertake international collaboration.

H2. *Population has a significantly negative relationship with international collaborative research output*. The greater size of population presumes the bigger internal capacity of knowledge since tacit knowledge embodies in people. Abundance of internal resource reduces urge to seek knowledge from external source.

H3. *GDP per capita has a significantly negative relationship with international collaborative research output*. One of IRC motivations to pursue research fund from external sponsor that cannot be supported internally. High income economies countries tend to have adequate fund to support R&D activities. Therefore, conducting IRC will not bring much incentive when sufficient research budget can be provided internally.

H4. *Geographical distance has a significantly negative relationship with international collaborative research output*. Short distance increase intensity people-to-people mobility due to less restrictions that is conducive for knowledge exchange.

H5. *Historical relations have a significantly positive relationship with international collaborative research output.* A long history relation between mother-colony and colonies will continuously exist and transform into modern cooperation (like economy, sosio-culturem education and research dimensions).

H6. *Cultural similarity or language similarity have a significantly positive relationship with international collaborative research output*. The similarities of language and culture have eased communication and coordination processes between researchers undertaking collaboration.

H7. *Membership similarity in intergovernmental organisations has a significantly positive relationship with international collaborative research output*. Organisation proximity bridge various interests of its members. This is supportive to conduct cooperation among the members.

H8. *International trade inflow has a significantly positive relationship with international collaborative research output*. Nation's openness in trade easing collaboration due to imported research materials are necessarily demanded to support IRC activities.

2.4 Knowledge and Innovation

This fourth sub-chapter focuses on understanding the concept of knowledge, knowledge flows and innovation. It begins with development of the knowledge paradigm in section (2.4.1), followed by explaining the concept of knowledge which includes codified and tacit knowledge as types of knowledge. Knowledge flows and the instruments of knowledge flows will be discussed in section (3). It continues with a description of the process of knowledge accumulation. Before the concluding discussion, the concept of innovation will be deliberated including the types of innovation.

2.4.1 Concept of Knowledge, Knowledge Flows, and Knowledge Accumulation

2.4.1.1 Concept of knowledge

Understanding the concept of knowledge has shifted over time. (Solow, 1956) introduced knowledge through the Growth Model, which defines as technological progress. Growth would not happen without technological progress. Unfortunately, the explanation of how technological progress occurred was limited. This situation has encouraged scholars to study the determinants of technology growth. The endogenous growth theory explains that growth happens because of technological progress (Rivera and Romer, 1990; Aghion, Peter and Maxin, 1998).

Continuing Neo-Classical Theory and Solow Production Function, Romer (1989) introduced technology progress as a combination of labor and capital. He tried to show that knowledge embodies in labour. Knowledge can transmit via human resource mobilisation. Thus, Greater population and capital flow have presumed to foster technology development leading to higher national productivity.

The traditional paradigm perceives knowledge as non-rival and partially-excludable good (Rivera and Romer, 1990). From a micro perspective, it has been difficult preventing other individuals from utilising knowledge since it is a public good (Fischer, 2001). Preventing others from having access to knowledge has led to decreasing the role of knowledge, instead of accumulated and developed. Without protection, competitive advantages will be difficult to achieve since everyone may copy and imitate easily. In short, protecting knowledge is challenging.

Knowledge defines as a public good with property rights that are rarely enforceable. It is seldom quantified or priced; sometimes it is codified, but more frequently tacit, and in any case, it is difficult or impossible to observe. All measures of knowledge are indirect, either

inputs to (years of schooling, manuals) or outputs of (human capital, patents, the unexplained residual in growth accounting) its accumulation (Navaretti and Tarr, 2000, p. 2).

Efforts to protect knowledge are well-developed since understanding the role of knowledge in the economy has been expanding globally. Knowledge is valuable to grow innovation and generate profit (Mankiw, Romer and Weil, 1990; Rivera and Romer, 1990). Efforts have been made to encrypt some knowledge to forbid undesirable users from obtaining knowledge (Fischer, 2001), for example, knowledge related to industrial strategies and innovation activities, which are the core of their production system. Another method to protect and restrict information is by applying a unique code on knowledge transmission to keep the knowledge confidential (Szulanski, 2000). At the global level, protecting knowledge has transformed into a more institutionally robust database by registering knowledge as intellectual property (IP). There are various types of IP, such as trade secrets, geographical indications (GI), industrial designs, trademarks, copyright, and patents (WIPO, 2019a).

Knowledge involves the multidimensions process. Knowledge can be seen as an input (embodied in labour) and as an output (technology and machinery) in the production process (van Oort and Lambooy, 2014). From a geographical context, knowledge may only be suitably produced in a particular place and time (Storper, 1999). Therefore, knowledge is strongly correlated to space for knowledge creation and knowledge diffusion.

After that, it is interesting to note what geography has contributed to knowledge formation against the conventional paradigm in which distance determines the likelihood of knowledge exchange. Individuals conceptually create knowledge, and this has made individuals play a central role in knowledge creation. In the meantime, individuals have relatively fixed locations. From a geographical perspective, knowledge attaches to space and hard to replicate or

exchange in other locations where individuals live in different locations (Storper, 1999). Knowledge is presumed unique to particular locations and encounters a challenge to imitate and learn over distance (Bathelt, Malmberg and Maskell, 2004). In the other view, epistemic idiosyncrasies possibly generate disparities among countries where some places receive advantages from endogenous knowledge resources leading to innovation, growth, and competitiveness, and the rest of the countries have underdeveloped knowledge because of limited knowledge sources (Glückler and Lazega, 2017).

The definition of knowledge is the result of elaboration between processes, interactions, and various dimensions. Van Oort and Lambooy (2014) defined knowledge as the product of particular processes including learning, research, testing, and adjusting undertaken by individuals who have the experience, capacity, and capability in academic subjects. Knowledge can also be created through an interactive process that involves actors with various backgrounds of knowledge and capabilities and allows discussion and sharing information with common objectives to resolve problems or achieve specific targets (Bathelt, Malmberg and Maskell, 2004). Furthermore, an illustration of knowledge can is like a cake consists of multilayers and multidimensional aspects (Buehl and Alexander, 2001). The knowledge is presumed to reside in single to multiple domains.

Knowledge can be classified generally into two areas, academic and non-academic knowledge (Bozeman, Fay and Slade, 2013)(see table 2.1). Scientific knowledge results from academic processes like research and development and several examinations (Buehl and Alexander, 2001; Hassan and Haddawy, 2015). Acquiring academic knowledge can be done through formal experience (such as a degree), within an institutional framework (university or academy), and through formal methods (classroom, seminar, conference, citation,

collaborative research) (Buehl and Alexander, 2001). The pursuit of knowledge is motivated by a person's curiosity and needs to seek new knowledge (Polanyi, 1966). Knowledge may not be deducible when it transforms into principle, algebra, convention, and assertion (Gertler, 2003).

Meanwhile, practical knowledge' is the type of knowledge commercialised or applied in the production process (van Oort and Lambooy, 2014). Non-academic knowledge may be found in machinery, production methods, and business strategies that manifest into patents and commodities (Kang and Dall, 2015). Economic transactions and production activities are the most common instrument in low-income economies countries to acquire external knowledge. However, both academic and non-academic knowledge can be nearly crucial if these are continuously re-established, are sources of inspiration, and stimulate further knowledge development (Buehl and Alexander, 2001; Adams, 2002; Lemarchand, 2012).

Table 2. 2 Comparison between Academic and non-Academic Knoweldge

Aspects	Knowledge	
	Academic	Non-academic
Institution	Universities/research institution	Firms
Purpose	Science and development	Commercial
Embodied	Individual	Organisational procedure (management), employee
Product	Publications	Patent and commodity
Method of Obtaining	Formal experiences, institutional based, and formal methods (for example academic degree, training, seminar, conference, citation	Casual, tend to be informal transmission

Source: Summary from Bozeman et al. 2013; van Oort & Lambooy 2014; Buehl & Alexander 2001; Gertler 2003

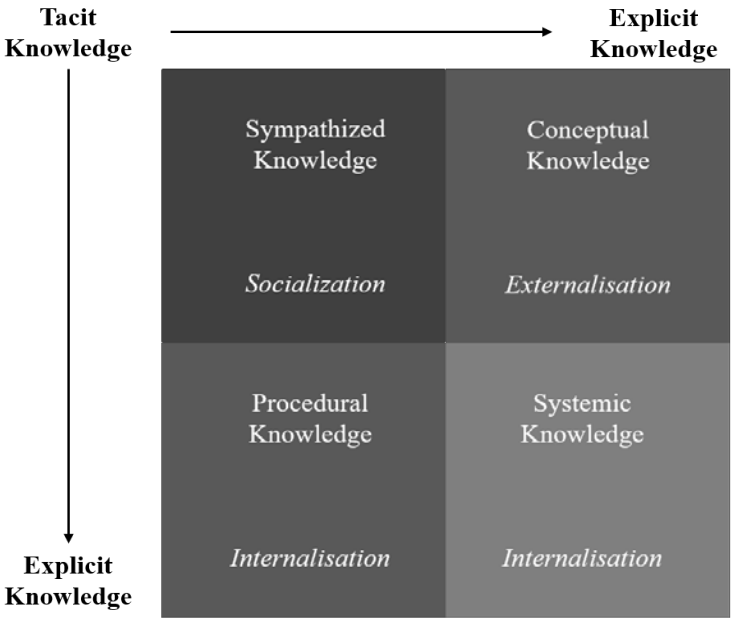
Activities of academic institutions represent academic knowledge influencing the economy and development. Universities generate local economy and stimulate development knowledge transformation into innovation through intensive R&D activities in a dedicated area. For example, outstanding innovation and technology resulted from Silicon Valley and Route 128 in the United States (US), Cambridge, and Oxford in the United Kingdom (UK). Having specialised in research and development will lead to institutional excellence. Research findings from academic institutions generate spin-off effects for industry within the spatial proximity (Varga, 2000). Industries utilise universities' research as a source of knowledge to create innovation and increase productivity (Smith *et al.*, 2014). The university is a mutual partner for industries to absorb external knowledge that beneficially supports its production process. Therefore, academic knowledge contributes to regional development performance after it has passed through transformation stages like publications, patents, innovation, and the production process.

Creating knowledge takes a process of communication and elaboration between tacit and explicit knowledge. Knowledge occurs due to social interactions and social exchanges through social communication (Glückler and Lazega, 2017). Social interactions have allowed the sharing of information, experience, and specific knowledge among individuals (Chua, 2001). Having communication through social interactions, such as friendship and membership, gives the privilege to access knowledge (Grandadam, Cohendet and Simon, 2012). In the meantime, access is a fundamental asset in the production process. This paradigm grows since access can acquire capital and knowledge. Hence, a collaboration between capital and knowledge accumulation may accelerate productivity.

There are several factors determining knowledge creation, both from internal and external sources. External factors usually greatly influence knowledge development and interaction

within an organisation and between organisations (Bathelt, Malmberg and Maskell, 2004). Similar to the endogenous growth concept that external knowledge generates growth and innovation (Romer, 1989). Increasing research and development budget, involving more expertise, and conducting collaboration can accelerate the knowledge creation process.

Furthermore, interpreting knowledge can be seen from two approaches: the category of knowledge share and the media choice to communicate. There are three ways to transfer knowledge: conventional channels (face-to-face meetings); written documents (reports, publications, letters, standard procedures, and guidelines); and by electronic means as media communications (like phones and video calls) (Chua, 2001). Knowledge shared is distinguished as tacit or explicit. Tacit knowledge means ideas, concept thinking, experience attached to a person or individual that is difficult to exchange with somebody else. Meanwhile, explicit knowledge is the knowledge that is easy to express, articulate, communicate, transfer to others, and be stored in various forms, like textbooks, pictures, and digital media. Explicit knowledge has characters and is objective and rational, articulated through narration, employing quantitative and technical terms, and mostly diffused via formal and structured techniques, legal forms, regulations, and procedures (Jasimuddin, Klein and Connell, 2005; Chilton and Bloodgood, 2012). Meanwhile, tacit knowledge is based on personal views and tends to be relative (rely on an individual's perspective), and is informal. There is less possibility of tacit knowledge being recorded or stored; it is difficult to transfer and dominated by feeling (Chua, 2001).



Source: adapted from Nonaka & Takeuchi, (1995)

Figure 2. 1 Comparison between Tacit Knowledge and Explicit Knowledge

People use tacit and explicit knowledge in four different ways when interacting socially (Nonaka and Takeuchi, 1995). These are 1) during socialisation, when collaborative activities are undertaken to share experience, by copying, practising, in informal communication, and discussion underlain by the trust; 2) by externalisation, when providing an explanation in which knowledge express using specific tools such as charts, models, prototypes, assumptions, hypothesis, metaphors, and pictures to help understanding and reflective interaction among actors; 3) by a combination, using elaborate sources of knowledge from all media (transmission) and actors to present knowledge in the most user-friendly way; 4) by internalisation, where the emphasis is on the learning process using experiences, such as training, experiments, benchmarking and program assistance (see Figure 2.1). Factually, 'grey' knowledge is found to exist between explicit and tacit knowledge. However, it is more fundamental to explore types of sharing knowledge by measuring 'the degree of explicitness' instead of tacit and explicit knowledge separation.

Measuring the degree of explicitness can be done using three indicators: codifiability, teachability, and complexity (Chua, 2001). Codifiability means the degree of knowledge expressed or translated into text or narration. This knowledge may be crucial and is popularly represented in regulations, guidelines, or grand strategies. The degree of codifiability gets higher when the knowledge is more explicit. Teachability is related to knowledge's ability to be shared through formal contexts, like in the education system. The higher the degree of tacit knowledge, the more difficult it becomes to teach and share it. Complexity deals with the number of essential features. More complex knowledge requires a more significant number of elements, a longer process, and more effort to share that knowledge.

Knowledge generally can be distinguished as "tacit" and "codified" knowledge. Tacit knowledge is attached to personal knowledge as a result of self-learning or utilising knowledge, and it is possible to classify it in a transfer scheme, for example, books, patents, or equations (van Oort and Lambooy, 2014). Bathelt et al. (2014) see knowledge in a simple way in which tacit is local and codified is global. Codified knowledge may be exchanged internationally with lesser constraints due to regulations being more flexible in globalization and advanced technology. Technological developments help reduce distances as a fundamental obstacle of knowledge flows, identifying how travel time decreases, and how online systems allow sending and receiving information without direct (face-to-face) interaction. Once tacit knowledge turns into codified knowledge, the transfer cost will be zero regarding location. Tacit knowledge is not easy to codify since it is not necessarily easily articulated. Transforming tacit into codified knowledge, especially in preparation and transfer, requires cost and particular efforts (Fujita, Krugman and Venables, 1999; Bathelty and Cohendet, 2014). In specific conditions, codified knowledge is naturally saturated and possible to be more valuable if integrated with temporary knowledge, either owned or embedded in tacit structures (Asheim, 1999).

Other parties generally use codified knowledge (patents and books) as part of commercialisation. Transformation of tacit knowledge into codified undertakes through study, specific skills and feelings, and legalised rules. In reality, not all tacit knowledge can easily convert to codified knowledge regarding IP, protection, and knowledge value. Moreover, codified knowledge belongs to a person when implemented under new conditions, such as experience, or transferred within a group (van Oort and Lambooy, 2014). Nonaka and Takeuchi, (1995) explained that this knowledge is dynamic, and in the following process, tacit knowledge can be structured, and conversely, codified knowledge may be expanded and embedded into persons.

Tacit knowledge has dominated in innovation generation. Transforming tacit knowledge into innovation involves a specific process of learning-through-interacting with internal knowledge (country) and external knowledge (beyond the country) (Gertler, 2003). This process reflects geographical factors as sources of knowledge. At a practical level, industries utilise tacit knowledge elaborated with the other production factors to generate production activities (Ambrosini and Bowman, 2001). Therefore, when this accumulates at an aggregate scale, it brings a significant impact on the economy. The condition may imply that economic activity is associated with tacit knowledge at a national level through an outstanding contribution to the production process (Howells, 2002).

2.4.1.2 Knowledge Flows

The neoclassical school believes technological knowledge is relatively equal between countries, while labour and capital may differ and possibly travel across different locations. The flow of knowledge follows the mobility of labour and capital. The more intensive labour

and capital inflow to a country will foster knowledge diffusion leading to increased knowledge accumulation. In combination with the other production factors, this has generated new knowledge and innovation within a country. Therefore, migration and capital flow have stimulated disparity between countries' technological knowledge (Romer, 1989). For example, many countries have implemented a relaxation of trade and investment policies to boost international trade and FDI to harvest advantages from more significant knowledge inflow (Armstrong and Taylor, 2000).

The importance of knowledge flow initially came from the endogenous growth model. The divergence growth between countries generally towards a condition of equilibrium (Rivera and Romer, 1990). If a country has a low capacity for technology-knowledge, it will increase labor growth to leverage total output and achieve higher growth (Mankiw, Romer and Weil, 1990). Alternatively, some countries may import technology and knowledge from other countries with a more abundant supply of knowledge. This strategy is more affordable than growing internal knowledge. In the meantime, countries with sufficient human resources in the technology-knowledge sector tend to invest more knowledge (as capital) to leverage their capabilities. Nevertheless, the model suggested that low labour productivity and lack of endowment capacities such as infrastructure, politics, security, and law enforcement have stimulated countries' disparities.

Knowledge is a public good with non-restricted access (Stiglitz, 1999) and can flow from one actor to another when they reside nearby (Jafee, Trajtenberg and Henderson, 1993; Agrawal, Kapur and Mchale, 2008). Co-location helps exchange knowledge rapidly since a shorter distance reduces knowledge transfer constraints and risks (Agrawal, Cockburn and Mchale, 2006). Meanwhile, greater distances between two countries lead to increased travel costs and

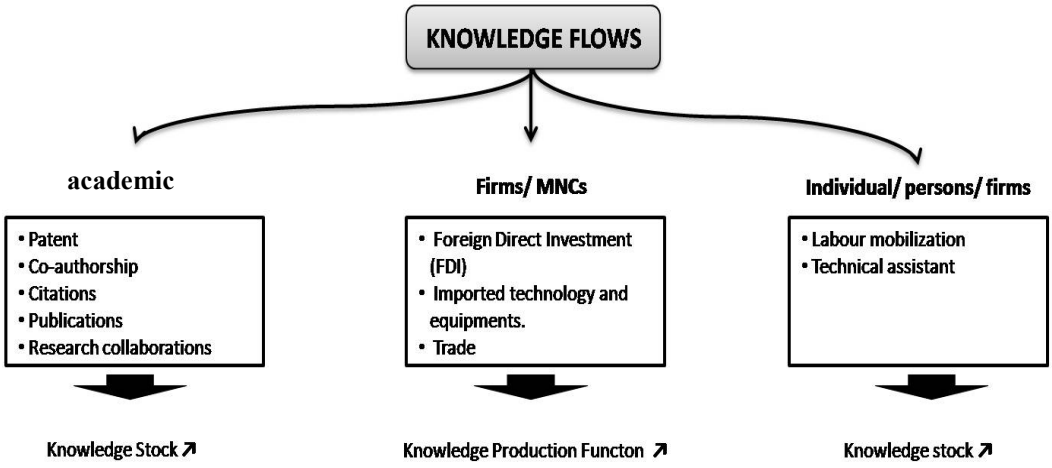
more difficulty building and managing knowledge flows. However, several policies may be able to lessen the cost of travel by promoting more incentives to attract migration of skilled human resources and FDI, fostering foreign knowledge spillover to local business by promoting collaborative production and accelerating infrastructure development in information and communication technology (ICT) and transportation sectors (Adams, 2002; Benneworth, Charles and Madanipour, 2010; Dominicis, Florax and de Groot, 2012; Lengyel *et al.*, 2015; Lengyel and Eriksson, 2017).

In the meantime, the growth of competitiveness has motivated many countries to acquire external knowledge to leverage capacity to support development (Caiazza, Richardson and Audretsch, 2015; Cruz-Gonzalez, Lopez-Saez and Navas-Lopez, 2015; Ferreras-Méndez *et al.*, 2015; Chirico and Salvato, 2016). Knowledge accumulation is fundamentally crucial in determining performance in producing new knowledge and growing innovation (Kafouros *et al.*, 2015). Better performance in knowledge creation and more incredible innovation in production will stimulate higher economic growth.

At the micro-level, acquiring external knowledge helps industries improve their capacity, proficiency and spills over to impact networks (Freshwater, Sherwood and Drury, 2006; Erden *et al.*, 2014; Aydinoglu, Allard and Mitchell, 2016). New knowledge is also needed to undertake R&D and promote research findings in higher levels, such as producing innovation (patents) and commercialising mass productions (Caiazza, Richardson and Audretsch, 2015). This situation represents in university-industry relations. The industry utilises research universities' findings to avoid 'knowledge lock-in,' as this is contra-productive to industry objectives to achieve maximum productivity (Mudambi and Navarra, 2004). Acquiring new

knowledge helps achieve production process efficiency that can increase industry competitiveness (Cruz-Gonzalez, Lopez-Saez and Navas-Lopez, 2015).

The mechanism of knowledge flow describes from the multi-level analysis. At the micro-level, the flow occurs when an individual produces an idea, then it is studied by another person (Peri, 2005). Other individuals' learning process implies that knowledge has been legally exchanged across different individuals by imitation, copying, and absorbing ideas in an academic context (Griliches, 1990b).

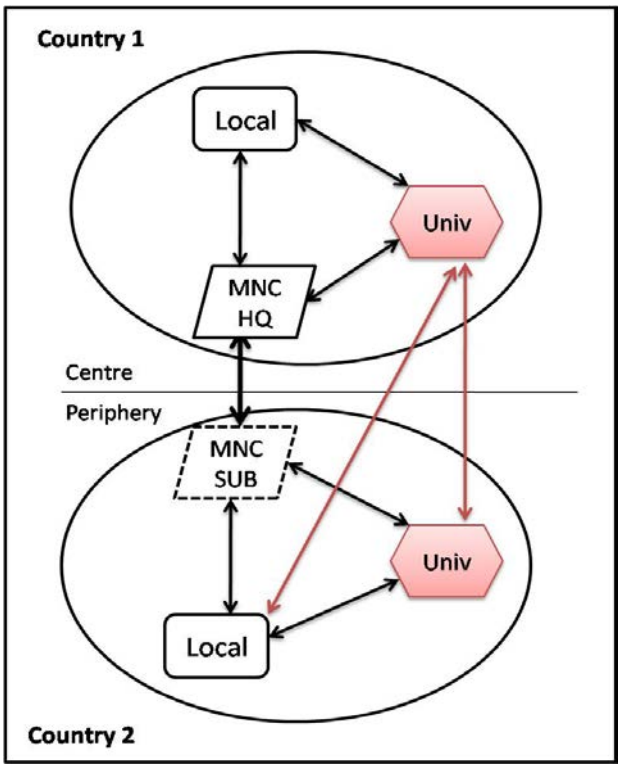


Source: Author, summarised from Abreu et al., (2015; Coe et al., (2009); Hoekman et al., (2009); Peri, (2005)

Figure 2. 2 The Transmissions of Knowledge Flows

Furthermore, knowledge can diffuse nationally and internationally (Onyancha and Maluleka, 2011). Knowledge transfer using sharing and discussion, teaching, and research collaboration between institutions in different cities (Peer and Stoeglehner, 2013). Besides, knowledge exchanges using several means of transmissions such as economic mechanisms (international trade, FDI), migration mechanisms (labour and technical assistants), and academic mechanisms (patent, citation, co-publications, and research collaboration) (see Figure 2.2)

(Peri, 2005; Coe, Helpman and Hoffmaister, 2009; Frenken, Hardeman and Hoekman, 2009; Abreu, Faggian and Mccann, 2015; Lengyel and Leydesdorff, 2015; Lengyel and Eriksson, 2017). Nevertheless, diffusing knowledge through labour mobility has a shortcoming of inefficiency as it is time-consuming to resolve complex procedures affecting the cost. Also, migration is not always in line with competitiveness since there is no guarantee that ideas or concepts always follow an individual's mobility (Argote and Ingram, 2000). Alternatively, research collaboration has several strengths for knowledge diffusion, for example, cost efficiency, and it is flexible and responsive to global dynamics (Szulanski, 2000; Aydinoglu, Allard and Mitchell, 2016).



Source: Author, developed from Ribeiro et al., (2014)

Figure 2. 3 International Knowledge Flows

In more complex interactions, knowledge diffuses across regions and sectors simultaneously (Figure 2.3). The condition happens when universities' knowledge transfers to the industry in local and international networks (Ribeiro *et al.*, 2014). Some factors have stimulated the interactions like demand for expertise (Audretsch, Link and Peña-Legazkue, 2013); capital

investment (Woerter, 2012); resolving problems and challenges and; creating new knowledge and growing innovation (Hall, 2004; Arvanitis, Kubli and Woerter, 2008). Furthermore, knowledge potentially flows using five approaches: 1) international research collaboration between local universities and those abroad universities to carry out scientific studies; 2) collaborative research between universities and a Multi-National Corporation (MNC) in Head Quarter (HQ) office where research findings have operationalised into a patent; 3) FDI as a follow up of patent implementation from MNC to global companies; 4) local connectivity between universities and local companies to apply research findings; 5) a preliminary study between a transnational company and local university, before foreign capital investment implemented in targeted countries (Figure 2.3). Media used to transmit knowledge can be seen in the form of publications, patents, licenses, capital, and spin-offs (Fagerberg, Srholec and Verspagen, 2010; Cappelli and Montobbio, 2014).

By process, knowledge flows classify into non-presented or presented material diffusion. The presented material includes purchased machinery and technology like computers, equipment, tools, and intermediate material (to assemble) in the economic context. The process of knowledge absorption is undertaken during production activities. Utilising purchased machinery and technology in production processes, elaborates the knowledge absorption process. Meanwhile, non-presented knowledge diffusion occurs through explanations from handbooks, brochures, patent implementation, seminars, workshops, publications, and human resource mobilisation. The other transmissions are joint capital, mergers, acquisitions, and collaboration in the production process.

The sufficient prerequisite factors, both for the inventors (as sources of knowledge) and the recipients (users), determine knowledge diffusion probability. As described at the beginning of the sub-chapter about knowledge creation, social interaction has been the baseline knowledge

flow mechanism. Social elements help bridge two different actors to be interconnected. These elements include similar characteristics (background, capacity, interest), social bonding (friendship), and mutual trust as the foundation of connectivity (Scott and Stropper, 2003; Peri, 2005; Cappelli and Montobbio, 2014; Percezione, Imposta and Soggiorno, 2014). Like friendships, nationalism, alumni, and colleagues, social relations influence the tendency to share knowledge (Bell and Zaheer, 2007). Social relationships built from trust and familiarity increase the possibility for knowledge to diffuse across regions. For instance, historical relations between regions have been an underlying factor behind knowledge flows. Having a colonialism experience between two regions encourages them to have larger flows than regions without having similarities (Sooryamoorthy, 2009). These components can be called the non-physical prerequisites of knowledge flows and fundamentally needed as a baseline for connectivity, although the components are physically unseen.

The following requirements are more physical and operational aspects that are needed to transmit knowledge. Actors should have a particular design and method to convey knowledge developed based on the creator and user's interests and characteristics (Bathelt, Malmberg and Maskell, 2004; Bathelty and Cohendet, 2014). In other words, selecting suitable media to transmit knowledge is essential to ensure knowledge flow optimally and with fewer restrictions. It should be managed in terms of frequency and quality, which are somehow sensitive to external shock. Therefore, defining the type of method to transfer knowledge will affect the sustainable flow of knowledge.

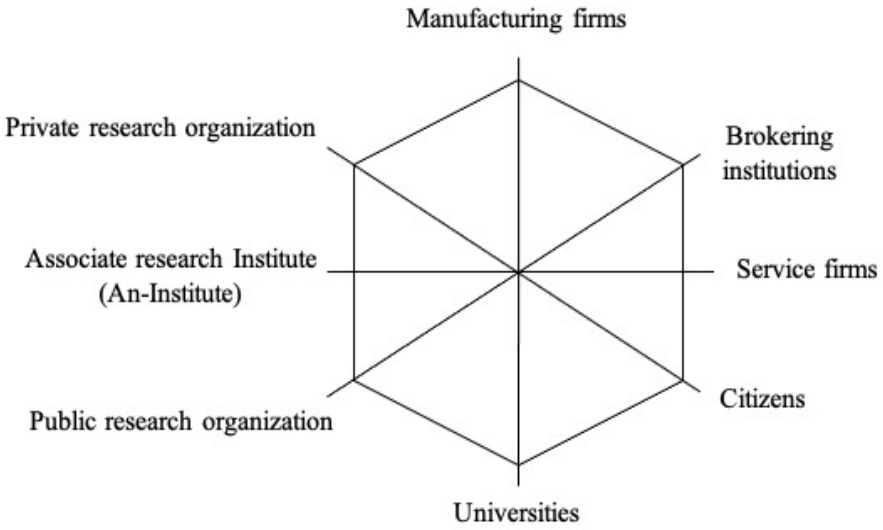
Geographical element is another physical factor of knowledge flow. The propensity to transfer knowledge increases when the distance reduces between regions. A shorter span between regions significantly correlates with a greater flow and higher intensity of interactions. Physical

closeness helps build connectivity and communication among regions (Frenken, Ponds and van Oort, 2010; Hoekman, Frenken and Tijssen, 2010b). Distance has reduced the probability of knowledge to flow accounted for 3% for every 621 miles span between regions (Peri, 2005). Greater distance hamper knowledge from spillover inter-region (between region). However, although regions with a distance between them usually have a low frequency of flow, knowledge diffusion has a more significant impact (Onyancha and Maluleka, 2011).

Furthermore, the development of infrastructure and technology has contributed to shortening the distance (in the context of knowledge exchange efforts) (Bayoumi, Coe and Helpman, 1999; Hoekman, Frenken and Tijssen, 2010b). The more developed the technology, and with sufficient networks, the higher the likelihood knowledge will diffuse. It is interesting that when the technology gap is widening, knowledge tends to flow mainly from countries with advanced technology to underdeveloped countries (Peri, 2005). It is similar regarding the disparity in regions that stimulate knowledge diffusion using labour migration and capital flows. These phenomena construct several indications as follows. *First*, external knowledge is acquired to overcome the issue of left-behind technology caused by limited knowledge capacity. *Second*, transferring knowledge will stimulate people to undertake further research to create new knowledge and keep technology updated. *Third*, developed countries have an opportunity to learn from underdeveloped regions to create innovation that has not existed or experienced before. For instance, developed countries undertake research to study disease in emerging countries, resulting in vaccine production. This type of medicine may never have produced in developed countries. *Fourth*, the spirit of commercialisation might stimulate knowledge flow. Inventors may receive benefits from knowledge exchange activities as manifested from knowledge protection.

2.4.2 Concept of Innovation

Innovation has recognised as the central engine to accelerate economic growth. As the heart of technological change, innovation development relies on accumulating various types of knowledge. Determinant innovation factors include how much knowledge can be acquired and how the selection process and richness of knowledge are suitable to grow innovation. Implementing these stages will demand active participation from various stakeholders such as citizens, brokering institutions, service firms, manufacturing firms, private research organisation, associates research institute, public (government) research organisation, and universities as a source of knowledge (Figure 2.4).



Source: Author

Figure 2. 4 Actors Related to Innovation Activities

Innovation relates to implementing new ideas or concepts that manifest into products, processes, or services. Since the new idea or concept has not been commercialised, it cannot be acknowledged as innovation. The argument refers to the definition of innovation as the creation of new concepts, designs, or schemes which have been implemented into goods, methods, or services, and result in the generation of economic development, using labour and earning financial gain to create the following innovation (Popadiuk and Choo, 2006). Innovation is the result of cumulative learning and social elaboration, which relies on tacit

knowledge that cannot be traded mutually (Crescenzi, 2005). Innovation should combine, modify, and create new knowledge and diffuse within external organisations. In other words, innovation requires a long-term and sustainable process undertaken by individuals or within an organisational framework (Howells, 2002; Rodríguez-Pose and Crescenzi, 2008). A new idea or concept articulates users' expectations and preferences about new products or the new production process methods (Fischer, 2001; Gertler, 2003; Dominicis, Florax and de Groot, 2012). Therefore, the new idea has been produced from knowledge accumulation: acquiring, sharing, and diffusing into its internal framework. A new idea associates with new knowledge manifested into products, processes, and services. This new knowledge has produced the output of innovation like technology, market, and organisational characteristics.

Innovation is generated from a reciprocated cooperation through a complex system. This system involves knowledge production, geographical factors, and economic exchange (Lengyel and Leydesdorff, 2015). Geographical factors like co-location between actors help foster intensive cooperation, ease knowledge flows, and reduce the cost for knowledge diffusion, technological exchange, and labour mobility between them. These situations are conducive to growing innovation since these may trigger a greater probability for knowledge accumulation and knowledge selection that can fit innovation activities.

Understanding the concept of innovation can be seen practically from the category of innovation. Categories of innovation were initially promoted by Afuah, (1998), who classified innovation based on three areas (technological innovation, market, and administrative) (Figure 2.5). *First*, technological innovation results from the knowledge production process that has accumulated material, system, equipment, and expertise. The outputs from technological innovation are design, processes, products, and services. Process innovation should be able to

improve efficiency and productivity. Besides, new products should meet market expectations. Therefore, technological innovation can overcome problems and challenges internally (within the organization) and externally (market) and improve aggregate productivity.



Source: author, adopted from Afuah (1998)

Figure 2. 5 Classification of Innovation

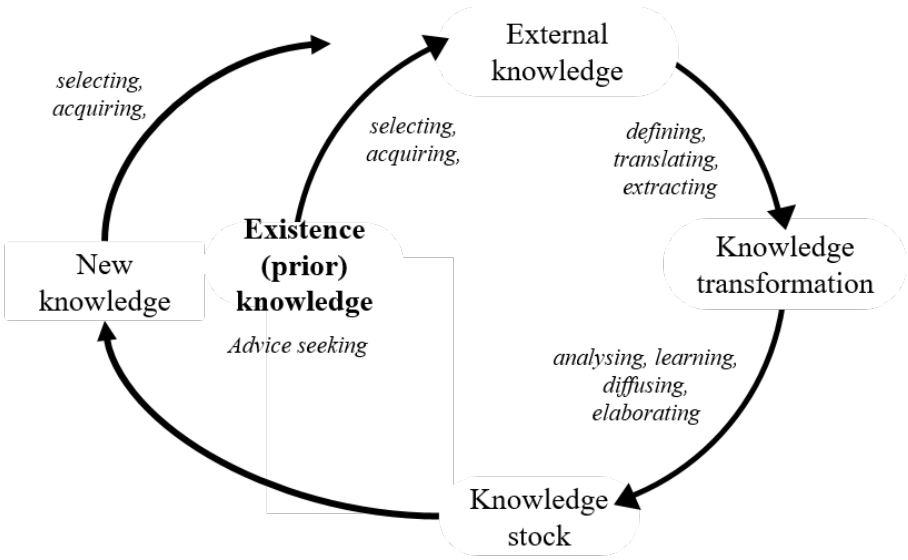
Second, market innovation defines as a new knowledge attached to the distribution and sales process. These embody in products, prices, places, and promotions. This innovation aims to increase sales and enlarge the new products market that increases the total output value. *Third*, administrative innovation aims to ensure that the internal organisational strategy efficiently supports the production process. Organisation innovation consists of strategy, structure, systems, and people. This innovation type has been the key to implementing the two previous innovations since it combines people and systems. Bringing innovation within an organisation means operating the system efficiently. Institutions consist of a framework of everyday habits, routines, practices, and regulations that manage individual interactions.

From these three areas, innovation deals with technology itself and how the technology implemented in 1) innovative production (work) processes and operating systems; 2) market

application through innovative distribution and sales strategies. In other words, new knowledge will affect the production process, organisational systems, and the market.

2.4.3 Transformation of Knowledge Flows into Innovation

Knowledge requires knowledge. As seen from figure 2.6, receiving new knowledge (from external sources) demands previous knowledge and a sufficient background of experience to extract, understand, evaluate and articulate it into structured forms (Meusburger, 2008). The paradigm is built from the role of knowledge as a filter for other knowledge, for example, selecting and extracting knowledge that is suitable to be used for specific purposes. The first filter functions in translating technical terms, learning new skills, analysing conditions, and perceiving experiences. The following role of previous knowledge is filtering specific knowledge that deals with a general paradigm or truth. It works regarding belief, ideology, politics, myth, norms and tradition, and social value. It is beneficial to use as a selection process to decide what type of knowledge will either be accepted or refused.



Source: author

Figure 2. 6 Existing Knowledge Determine the Process of Knowledge Accumulation

Preference is another factor of knowledge accumulation. Acquiring knowledge is relevant to a specific interest that is usually linear with an objective (Schubert and Glanzel, 2006). Preference can be manifested in various forms like the way (media) used to obtain knowledge, type of knowledge, degree of effort to seek and absorb knowledge, and utilise knowledge. An interest usually deals with a personal view, which is challenging to identify and measure. An alternative method to describe preference in the accumulation process of knowledge is defining characteristics between knowledge actors. Similarity helps to reduce the constraints to obtain and adopt knowledge. Later, similarity expresses through proximity.

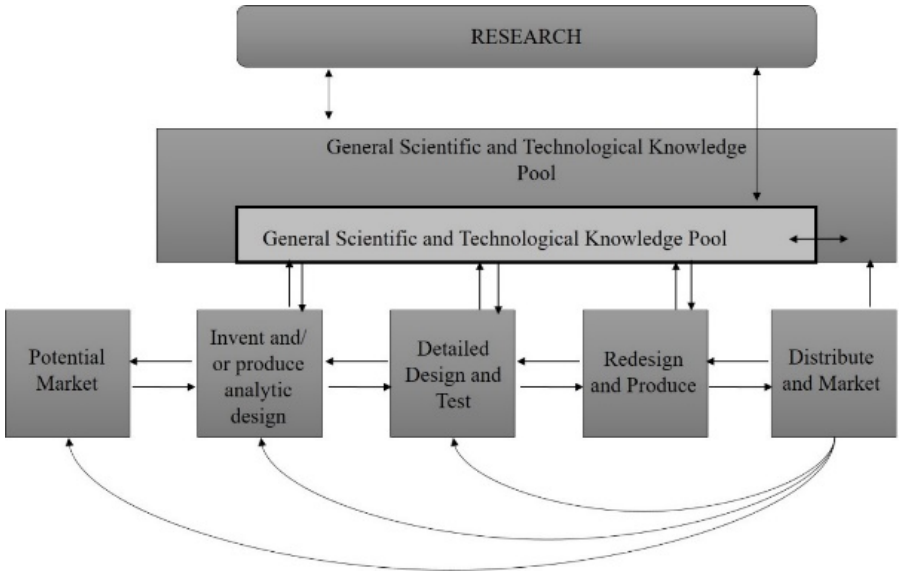
After the selection process, knowledge will be stored for accumulation as a stage in the knowledge cycle process. Two approaches can achieve this. *First*, specialisation reflects a learning process undertaken by individuals to copy, absorb, elaborate with existing knowledge, and transform it into new knowledge. This process presents some advantages: it has a rapid storage process, acquires more excellent knowledge, and is more sustainable in the long term (Stokey, 1988; Young, 1991; Navaretti and Tarr, 2000). The approach has generally resulted in new methods or approaches as a product of new knowledge. *Second*, transforming knowledge into capital (as a production factor). Imported knowledge from final products, equipment, technology, and methods will compile knowledge as a stock of capital since knowledge embodies machinery and methods (Romer, 1989; Dall'erba and Le Gallo, 2008; Garrido-Yserte and Gallo-Rivera, 2008). This method has several weaknesses in terms of cost, time, and space. It makes this approach more suitable for short-term development strategy, particularly for countries with limited internal capacity to produce knowledge (Navaretti and Tarr, 2000; Ponomariov and Toivanen, 2014b). It can be said, imported technology to stimulate innovation majorly undertaken by GS countries who have limited resources to create new knowledge and grow innovation internally.

The capacity of knowledge production and innovation performance are distinctive between level of income-economies countries. Grossman and Helpman (1991) concluded that developed countries have an immense stock of human capital with strong academic capacity leading to intensive knowledge production. The greater volume of publications and IP (as proxies of innovation) represents intellectual capacity. It makes them have higher economic growth than developing countries since innovation has been produced widely and continuously. On the other hand, developing countries may gain an enormous assortment of knowledge from imported productions to increase their knowledge capacity and accelerate the economy (Grossman and Helpman, 1991). Peri (2005) argues that imported knowledge cannot directly generate the economy and triggers dependency, mainly when the volume of productive inputs are insufficient. Also, imported knowledge and technology seem to create new knowledge due to the small opportunity for knowledge spillover.

Generating innovation without acquiring external knowledge is challenging. Many scholars have believed that external knowledge is a source of innovation. Fischer (2001) explained that transforming knowledge to innovation requires at least three primary processes: selection, absorption, and elaboration with current knowledge. Selection means seeking knowledge that is suitable for organisation goals. The following stage acquires knowledge based on ability and current capacity. Absorbed knowledge will combine with existing knowledge to produce innovation and further new knowledge since an elaboration between codified (explicit), and implicit knowledge can generate innovation.

The transformation of knowledge to innovation identifies from two perspectives: Evolutionary and Neoclassical models. The Evolutionary or neo-Schumpeterian model defines innovation

as an interactive process with purposes to: overcome problems, reduce barriers, increase the quality of products and service, achieve efficiency and improve the quality of work (Fischer, 2001). The transformation process majorly investigates at the firms' level of analysis. The process describes an interactive relation explaining innovation as a chain-link framework between several activities and interconnected through a loop. Two fundamental factors have driven the concept: 1) a research result that creates new knowledge and accumulated within the knowledge pool system of an organisation; and 2) a response from a market's dynamics like trends, interests, and preferences (see Figure 2.5). The innovation process started with combining the novelty of research findings (technological knowledge) and the market's preference. It continued with analytical design to generate a new product or process, then finalised with product testing and redesign before production on a large scale. The following stages are checking for quality assurance and distributing to markets. The downstream stages within the central chain are linked with short loops, which represent a direct response. Meanwhile, longer loops show feedback from the market to the upstream process.



Source: (Fischer, 2001, p. 4)

Figure 2. 7 Interactive Models of the Innovation Process

The Interactive model (Figure 2.7) shows two mutually interconnected acts of cooperation. The first activity occurs within the organisation where knowledge and science have been applied in product innovation. The second cooperation activity involves external parties like customers, suppliers, universities and research centres, and business rivals. These interactions may work simultaneously but sometimes are contradictory because of different interests between them. External and internal interactions have made knowledge transformation into innovation a complex system.

The second concept is called the Neoclassical model or popularly Knowledge Generation and Diffusion (Fischer, 2001). It starts with an assumption that the creation and absorption of knowledge conveyed in a linear process. The process involves sustained and integrated interaction between internal and external stakeholders, which are interdependent. Innovation as the output of knowledge transfer.

The use of networks provides another approach to acquire external knowledge. For instance, in the production sector, firms have simultaneously interacted with customers, suppliers, competitors, and partners. The preferences and interests of firms are crucially pivotal in determining their business, particularly in understanding the market, projections about future trends, and improving their competitive advantage. The following stage is research and development to create innovation through collaboration with similar firms and universities. These initiatives are beneficial in the productive sector, like firms, to improve their performance. Meanwhile, in academic society, universities acquire external knowledge by undertaking research collaboration, visiting fellows, enlarging academic sources (like libraries, laboratories), conducting guest lectures, and increasing academics' activities (such as conferences, seminars, calls for papers, exhibitions) for widening networks with global scholars.

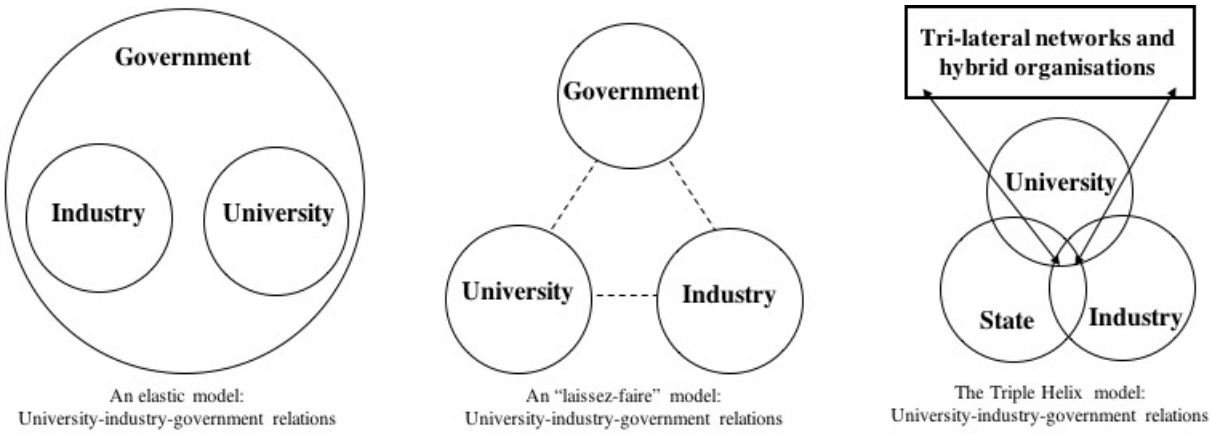
Knowledge spillover conceptually takes place since it is naturally part of public goods. Codified knowledge is accessible for anyone and can potentially be utilised to generate new knowledge. In a further stage, an intensive R&D activity can produce innovation. Knowledge is personally attached to an individual when knowledge is not totally codified. This has been an underlying factor that innovation activities are likely more intensive when researchers or scientists work close to each other (Bottazzi and Peri, 2003). Therefore, knowledge tends to flow easily due to geographical proximity. Non-codified knowledge is sensitive to geographical factors.

A study by Bottazi and Peri (2003) demonstrated spillover effects on innovation generation in Western Europe diminish according to expanding geographical distance from R&D activities as a source of innovation. Enlarging twice R&D in a region brings small effects (2-3%) on patenting activities in other regions (located 300 km). Contrarily, the effect is getting larger (5-6%) when regions reside close to the border (100km). The finding strengthens the thesis that knowledge spillover occurs by an intensive interaction between researchers who located each other. Geographical proximity helps to ease people-to-people mobility (like travel more frequent), and thus, non-codified knowledge diffuses less barriers.

2.4.4 University-Industry Relation

A relation between universities and industries popularly explains through the 'Triple Helix' (TH) approach (Etzkowitz and Leydesdorff, 2000). The role of universities in S&T activities and innovation development has grown since the military's contribution dimmed post-Cold War (Mills, 1958). A "Trilateral Power" emerge as a new collaboration of government, industry, and university (Braczyk, Cooke and Heidenreich, 1998). Etzkowitz and Leydesdorff

(2000) reveal TH in three different models. The first TH model describes government strongly determines industry and academia and directly incorporates with them. With some limitations (top-down and rigid regulations), this model exists in most socialist countries, like former Soviet Unions, Eastern European countries, North Korea, China, and Vietnam. The following model shows that each actor has forcefully separated by their formal circumstances leading to the weak interconnection between them, for instance, in the US and Sweden. As an improvement from the last two models, the third TH model focus on two main elements: 1) infrastructure of knowledge as a result of synergy roles and responsibility in research and science activities between university-industry-government (UIG); 2) a hybrid organisation as a centre of interconnection between them (see figure). This arrangement aims to grow an innovative ecosystem comprising academic spill-over industry, tri-lateral collaboration to accelerate knowledge-based-economy (KBE); industry association; public laboratories, and government research centre.



Source: (Etzkowitz and Leydesdorff, 2000, p. 111)

Figure 2. 8 Model of University-Industry Relation

Research in Asia seems inadequate to implement the TH model, while most countries and regions attempt to adopt TH's last model. In order to strengthen trilateral cooperation, some

issues have arisen such as national policy in regards to S&T activities, research funding, low capacity of researcher and human resource in universities as the primary driver of knowledge production, and the dynamics of collaboration between researcher and insufficient research infrastructures (Khan, Moon and Park, 2011). Building strong cooperation between universities and government is fundamentally needed to overcome these by starting a collaboration for innovation and research projects (Khan and Park, 2012). Strengthen research capacity potentially ease knowledge transfer university-industry through the innovative-collaborative project.

2.4.5 Economic Value and Path Dependency

A path dependency in knowledge flows and innovation creation draws attention in academic literature (Pierson, 2000; Martin and Sunley, 2006). Most of the literature has stressed on instruments to achieve scale economies through an economic perspective, especially the standard of knowledge transfer. Investigating the path dependency of knowledge transfer generally focus on innovation (Langlois and Savage, 2001). New knowledge creation is less generating economic growth than implementing new knowledge in the productive sector through innovation (goods and service) (Fagerberg, Mowery and Verspagen, 2008). Applying new knowledge in productive sectors (like industry) has more robust parameters to be valued from an economic perspective. In essence, the path of knowledge creation widely investigates through the economic dimension with established indicators, like innovation.

Innovation associates with industry. A conducive business environment has been a fundamental element in knowledge diffusion, especially transformation from knowledge into its production sector application (Fagerberg, Srholec and Verspagen, 2010). Nevertheless, the business sector's needs to grow innovation commonly are less be accommodated in NIS policy, although fundamentally contributed to national product (Narula, 2002).

National policy for S&T and the national innovation system (NIS) strongly relates to formulating a path dependency in knowledge diffusion and innovation activities. Political systems and institutions are pertinence in knowledge diffusion (Pierson, 2000; Whitley, 2002). Politics and government bodies determine national innovation development over their authorities and policies (Rose, 1990). The institutions facilitate economic relations between the actors of knowledge transfer and provide the legal framework to support a favorable R&D environment; once these have been established, it increases an opportunity to achieve economies of scale (North, 1990).

NIS conceptually consists of research infrastructures, policies and programs, legal framework, and institutions as policy' actors (Fagerberg, Mowery and Verspagen, 2008). Institutions play a central role in NIS's structure, especially for policy design and policy implementation. Institutions can be classified as follow: 1) core institutions-conduct R&D activities such as universities, public laboratories, research institutes, and private research centre (Mowery, 1998); 2) policymakers (central government and local government); 3) research partners (industries, funding organisation); 4) users (firms, societies) (Lundvall *et al.*, 2006; Lengyel and Leydesdorff, 2011; Hajek, Henriques and Hajkova, 2014).

As a part of innovation activities, knowledge diffusion involves at least three processes: selection, adoption, and retention. The processes are integrated, inter-dependence, and simultaneously in a time cycle. An integration process from acquiring external knowledge into creating new knowledge has specific characteristics like incremental development of standards and certain adjustments (Malerba, 2004). Such conditions imply that the process of knowledge transfer and knowledge creation has been diverse across sectors and industries. For instance,

IPR, academic standards, and basic research are fundamental for biosciences and medical sciences. Meanwhile, the automotive, food, and beverage industries emphasise consumer and suppliers relation (Fagerberg, Mowery and Verspagen, 2008).

Transforming knowledge into innovation primarily represents by university-industry relations. Universities or industries are generally locked into knowledge path since universities' intellectually is a source of knowledge for the industries to generate innovation(Whittle and Kogler, 2019). Historically, universities depend on industries to financially support basic research and experiments (Langlois and Savage, 2001). Either universities or industries are incapable of changing to a new position regardless of each part favoring doing it, which is in economy named 'penguin effect'(Katz and Shapiro, 1985; Garud, Kumaraswamy and Karnøe, 2010).

To continuously produce new knowledge, universities need to enhance their knowledge capacity by undertaking international research collaboration. Universities naturally cooperate with initial collaborative research partners with a superior reputation as standard cooperation (Meyer, 2007). For instance, collaborative research in Nano-technology will directly involve the high-rank countries in this academic subject like the US, Germany, China, South Korea, and the UK (Bai and Liu, 2016).

A high dependency path tends to be followed by the other path dependency. There are some critical elements of research collaborations forming path dependency: 1) knowledge capacity represented by institutions global ranking; 2) subject (science) specialisation ; 3) networks' strength to the other high-reputable universities (Han and Yim, 2018). Han (2018) also emphasise that the collaboration research path between universities is usually followed by a

collaboration with industry, especially cooperation at the practical dimension such as innovation. Transformation of new knowledge into production systems or economic activities sometimes neglecting the potency of dissimilarity across the nation. Therefore, path dependency in collaborative research and economic value is close to some essential factors such as historical process formed by a long run reputation.

2.4.6 Innovation Policy in ASEAN Member States and China

Since innovation is perceived as the key to leverage competitiveness and industry productivity, many countries have appointed innovation as a priority in national policy. Along with Science and Technology, Innovation is selected as the main agenda for ASEAN Economy Community (AEC) integration channel and institutionally documented in the ASEAN Plan of Action on Science, Technology, and Innovation (APASTI) 2016- 2025 (S. ASEAN, 2017). Following regional policy, the Ministry of Science and Technology is responsible for designing innovation policy, commonly found in China, Philippines, Malaysia, Indonesia, and Vietnam (Ambashi *et al.*, 2018), while Singapore created Economic Development Board to generate innovation activities from the private sector (Lim, 2018). Creating a specific institution who responsible for research and innovation activities represents the direction of innovation policy. In most ASEAN member states (AMS), innovation activities are driven by the government, seen through national R&D investment sources majority from public funding (Cambodia, Myanmar, Laos, Vietnam, Indonesia, Brunei Darussalam, Philippines). However, some countries have encouraged innovation from the private sector and demonstrated enormous contribution to national R&D investment than the government, such as Singapore (72%), Thailand (70%), China (62%), and Malaysia (57%) (OECD, 2008, 2012; Sun, Lei and Yin, 2018). Thus innovation activities will be more suitable to the industry's needs and lead to

industry productivities. How the innovation development has been arranged in policy in ASEAN and China will be explained as follow.

Innovation policy is generally structured in the national grand strategy for long term planning. Adopted from EU innovation policy, China released the National Innovation System (NIS), which operationalised into Regional Innovation System (RIS) legal framework (OECD, 2008; Li and Zhang, 2018). In the beginning, China focused on attracting FDI to gain capital inflow and knowledge accumulation, which are critical sources for innovation development, inclusive for R&D activities and human resources (OECD, 2013). These continued by building core-technology industries, namely Torch Program and supported by Spark Program, a combination between science park and business incubator conducive to knowledge transfer and innovation activities (Li and Zhang, 2018; Sun, Lei and Yin, 2018). Nanotechnology is a priority sector for leapfrog technology in the industry. Similar to China, in order to support R&D activities, Singapore launched Research Innovation and Enterprise (RIE) policy (2015-2025) that was implemented by increasing R&D spending (over 2.17% annually), managing the R&D expenditure effectively, promoting cluster industry (as a collaboration between universities and industries), and initiating tripartite (business, innovation, talent) home strategies to attract FDI, foreign expertise (as global talent) and international collaboration (Lim, 2018). Since Malaysia should deal with limited internal capacity (human resource, budgeting, and infrastructure) to support science and technology (S&T) activities, they launched a grand design policy of innovation and technology for 40 years (1980-2020) (Narayanan and Yew-Wah, 2018). There are six priorities in regards to Malaysia national policy: initiating a global talent pool, S&T-industrial cluster, increasing R&D spending and private contribution, providing an immense number of Ph.D. scholarships for the young generation, and reforming innovation agencies to accelerate policy implementation. In the meantime, Thailand started its innovation activities

by acquiring international knowledge by importing 2556 robots (in 2015), relevant to Thailand's economic backbone as 'global factories'. Another strategy was strengthening institutional capacity by removing the multi-roles from government bodies that carry out innovation policy, increasing the national R&D spending ratio to 2% of GDP, and providing incentives for research centres and universities demonstrating high performance on innovation activities (Rattanakhamfu and Tangkitvanich, 2018). Human resource development has responded by upgrading minimum qualification (Ph.D. level) of researchers (in science, technology, engineering, and mathematics -STEM), increasing the ratio of R&D staff up to 2500/ million population, and requiring State-Owned Enterprises (SOE) to allocate 1% of their profit to be invested in R&D activities (OECD, 2013).

Apart from middle economy countries, Vietnam exhibits impressive progress in innovation policy development. It began with removing government monopoly over S&T activities and releasing some research contracts to the public (Vi, Nguyen and Dinh, 2018). This has affected institutions' reformation, particularly the quadruple-helix collaboration between public labs, government, universities, and industries. Following institution transformation, the government continues reforming the bureaucracy system by creating a dedicated agency to promote S&T activities (both central and provincial level), adopting ASEAN's standard for S&T activities, and reducing tax for a high-tech intensive industrial cluster. Unlike Vietnam, the Philippines introduced the Filippinnovation strategy for the medium term (2000-2010), aiming to elaborate innovation as the primary orientation in most national development policies(Quimba, Albert and Llanto, 2018). The strategy implemented into five main programs: 1) Collaboration Research and Development to Leverage Philippine Economy (CRADLE); 2) Small Enterprise Technology and Upgrading Program for SMEs (SETUP); 3) Incubation Technology for Commercialisation (Technicom); 4) Human resource capacity improvement for researchers

and lecturer; 5) S&T activities as 'special purpose vehicle' (SPV) for poverty reduction. Unfortunately, institutions and bureaucracy reform and R&D investment have not been elaborated into the national policy, affecting slow S&T development and innovation creation.

The grand national design for innovation policy helps the government arrange their innovation development stage upon different periods. In other words, the national innovation design has directed the policy to be more focused and suitable with the current national condition that is critical for policy impact. The rest of AMS has not seen innovation as continuing progress divided into different stages that generally implement in a long-run period. It indicates by an absence of a grand national design for innovation development in Indonesia, Brunei Darussalam, Myanmar, Cambodia, and Laos (Ambashi, 2018; Ambashi *et al.*, 2018). Some problems have emerged such as unclear the government agencies which mainly responsible for the policy development and implementation, insufficient S&T activities, weak collaboration between government-universities-firms/ private, inadequate budget for R&D, low capacity of researchers (number, qualification, and experience) impacted on low research quality (Damuri, Aswicahyono and Christian, 2018; Rasiah, 2018). Most policies are established separately in different sectors (for example, education, research, and industry) instead of nationally integrated and synergised (Ambashi *et al.*, 2018). As a result, a lack of coordination between the government bodies in policy implementation appears in most AMS.

However, most of the AMS and China generally indicate a similar strategy to stimulate S&T activities and to grow innovation. Attracting more FDI inflow is selected as the main channel for knowledge diffusion from abroad, particularly for the industries (OECD, 2012; Rasiah, 2018). A limited internal capacity to create new knowledge and generate internal innovation has encouraged many nations to acquire external knowledge through this transmission.

Following the policy to invite more FDI, the government builds the science-park (techno-park and research-park) linking science and industry. Besides that, they create cluster industry and business incubators to promote research collaboration and knowledge spillover (Ambashi *et al.*, 2018).

2.4.7 Summary

Knowledge is essential for development. It helps to overcome challenges and achieve the goals by generating new knowledge and growing innovation. For instance, in daily living like economic activities and industries sources from academic knowledge. The process of knowledge transformation is strongly influenced by social aspects, from creation to accumulation.

At the specific level, tacit knowledge has contributed to the added value creation process through productivity improvement. Tacit knowledge drives innovation that affects technology (production), administration (systems), and market areas (sales and distribution). Knowledge attached to human capital can increase productivity through labour. As a result, the combination of innovation, labour, and capital altogether enlarges the total output. It has encouraged the acquisition of external knowledge that use for knowledge accumulation. Human capital, foreign direct investment (FDI), trade, and academic approaches are the popular means of transmission to acquire external knowledge that later are used for knowledge to flow. Furthermore, non-physical factors (historical relation, social background, the similarity of capacity and interest) and physical factors (distance, economic development, infrastructure disparity, information, communication and technology, and IT development) determine knowledge flows. All proximities significantly influence network development among knowledge actors.

However, the academic approach through research collaboration has more tremendous advantages in terms of time, cost, impact, and sustainability among the three types of knowledge flows. Collaborative research will have more excellent opportunities to acquire more tacit knowledge, mostly by industry, since it is valuable.

2.4.8 Hypothesis Development

H1. *Intra-regional collaboration has a significantly positive effect on patents*. Collaboration within region presumes more intensive conducted since geographical closeness has reduced constraints knowledge to flow.

H2. *Extra-regional collaboration has a significantly positive effect on patents*. GN countries have been excellent producing new knowledge that is fundamentally required by GS countries to generate innovation**.**

H3. *Trade openness has a significantly positive effect on patents*. Degree of country openness influence knowledge flow via imported technology, production inputs and machineries which are critically needed to undertake innovation activities.

H4. *Ratio of education spending has a significantly positive effect on patents*. Human resources development is the key determining performance of innovation activities.

H5. *Technology intensity has a significantly positive effect on patents*. Innovation activities demand for the adequate facilities, include existing equipment and machinery.

H6. *FDI have a significantly positive relationship effect on patents*. FDI is one of the channels to acquire external knowledge.

H7. *Labour has a significantly positive effect on patents*. Labour is crucially needed to support innovation activities.

H8. *GDP per capita has a significantly positive effect on patents*. Innovation activities require an immense and continued investment which proximate through GDP per capita. The higher level of income economies will affect the greater budget allocation for R&D activities.

H9. *Business environment has a significantly positive effect on patents*. Since patens associates with industry, sufficient business environment will be favourable to grow innovation.

2.5 Concluding Discussion

Studies about research collaboration have been investigated in many themes. Identifying motivations behind research collaboration at the levels of the micro (between individuals), the meso (between institutions or sub-nations), and also the macro (between nations or regions) are widespread and continuously conducted (Georghiou, 1998; Storper and Venables, 2004; Jeong, Choi and Kim, 2014). The other IRC perspectives may reflect from examining patterns and characteristics of collaboration, such as the determinant factors, favourable IRC sectors, and building the IRC process (engagement elements, mechanism, and approaches). The specific themes have grown to a broader scope of analysis such as GN–GS collaboration, South-South collaboration, and North–North collaboration (Arunachalam and Viswanathan, 2008; Jeffery, 2013; Collyer, 2016).

Recently, IRC studies have narrowed into specific topics like measuring the impact of IRC on researchers' outputs and institutions' performances (Van Raan, 1998; Lee and Bozeman, 2005; Gazni and Didegah, 2011; Foley and Della Sala, 2014). Then this was followed up by measuring the effect of IRC on innovation performance at firms and sub-national level, particularly analysis in collaboration on patents and patents citations (Ahuja, 2000; Ponomariov and Toivanen, 2014b; Ferreras-Méndez *et al.*, 2015). At the specific level, studies focusing on the impact of IRC on innovation have focused on measuring the effect of absorptive capacity (Tsai, 2009), diversity of collaborative partners (Sampson, 2007), degree of novelty innovation (Nieto and Lluis, 2007), technology intensity (Berman, 1990), linkage to technology growth at country-level analysis (Jalles, 2010) and examining the determinant factors in research collaboration (Maietta, 2015).

The literature of knowledge production and research collaboration is majorly from GN countries since they have extensively undertaken these topic studies. Diverse dimensions of knowledge and research cooperation have been explored to investigate the concept of knowledge production and knowledge flows. For instance, the various scope of the investigation (micro, meso, macro), collaboration characteristics (motivations, determinant factors, subject areas), the process of IRC, means IRC (co-publications, patent collaborations, patent citations), the impact of IRC (productivities, innovation, innovation systems), and relation to GN countries. On the other side, due to GS countries encounter research limitations (resources and capacity) and academic boundaries (knowledge, research, and publications), IRC performances are underdeveloped.

IRC has expanded from transnational to transcontinental cooperation over time, including GN–GS cooperation. GN–GN countries broadly initiate GS collaboration because of the supremacy

of GN countries in knowledge production. The disparity in intellectual capacity has triggered a greater dependency from GS countries in GN countries. As a result, unequal participation in knowledge production has been experienced by both sides. Since the literature on knowledge production and research collaboration produced by the GS is few and their academic outputs, GS countries' interest and views are hardly elaborated in most collaboration schemes. It can be seen from IRC implementation closely related to GN–GS relation stereotypes, for instance: 'scientific colonialism', 'donor-recipient relationship', 'mosquito research practice'. With insufficient academic evidence from GS countries, presenting the need to foster mutual partnerships, efforts to promote collaboration between GN countries and GS countries will be more challenging.

This thesis aims to bring empirical evidence on how knowledge production has coducted in GS countries. How knowledge production undertaken will describe using three main IRC elements: the structure of knowledge production, determinant factors, and the effect of IRC on innovation generation. Three main topics will specifically investigate: 1) how the network structure has been different overtime at regional level analysis; 2) how the pattern of determinant factors of IRC in GS countries has differed from GN countries; 3) how IRC brings advantages for GS countries as response to an indication of unequal participation and contribution in GN–GS collaboration. By presenting more evidence on how knowledge production has implemented in GS countries, it will be more feasible to promote mutual IRC, notably for equal participation and contribution between the GN and GS through collaborative research schemes.

CHAPTER III
RESEARCH METHODOLOGY

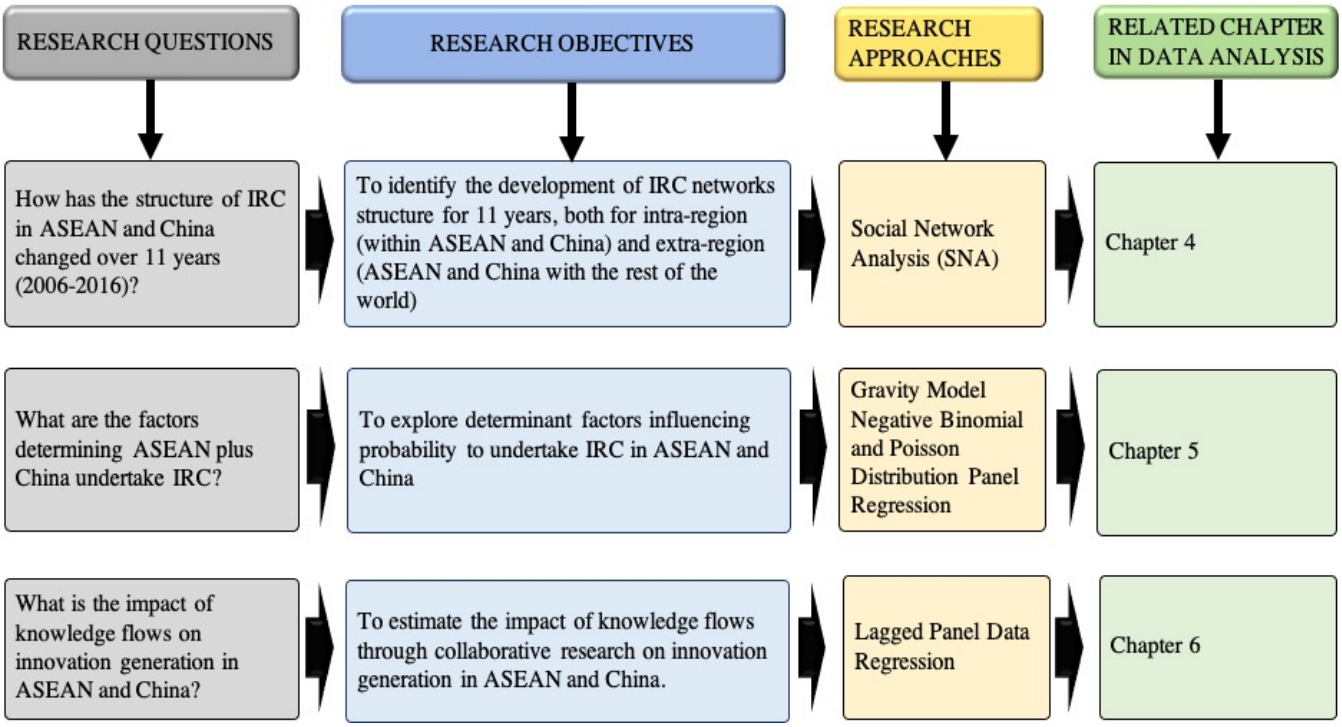
3.1 Introduction

This broad aim of this study is to identify knowledge flows in ASEAN and China through international research collaboration (IRC) which is discussed in three main aspects: the structure of the network, the determinant factors of IRC, and the impact of knowledge flows on innovation. This chapter discusses the research methods used to achieve the research objectives. Since every main objective differs, the research method varies and can be classified into three different types. The structure of this chapter is arranged as follows: first, it reiterates the research questions and research objectives; section two explains the research method for investigating the structure of the collaborative research network; section three elaborates the research method for examining the determinant factors of the likelihood of undertaking IRC; section four describes the research method for estimating the impact of collaborative research on innovation generation.

3.2 Research Aims and Objectives

The general purpose of this study is outlined by three main research questions with three objectives (Figure 3.1). These questions are designed to comprehensively illustrate collaborative research activities in Global South (GS) countries which are represented by ASEAN countries and China. Identifying IRC activities in GS countries is meaningful in academic literature since most of the studies related to IRC have been dominated by Global North (GN) countries. GN countries outweigh GS countries in terms of income economies, academic institutions, academic knowledge capacity and research activities leading to a greater volume of IRC. The imbalance of capabilities between GN countries and GS countries

presumes triggering the high dependency of GS countries on GN countries and unequal participation in collaboration of knowledge production. These have been encouraging some studies tried to promote mutual collaborative research between GS countries and GN countries. Unfortunately, studies of IRC from GS countries are limited, as well as the information on the number of co-authored papers produced. This study is pivotal by presenting the perspective of GS countries in quantitative analyses about unequal advantages from collaboration between GN countries and GS countries.



Source: Author

Figure 3. 1 Research Questions, Objectives, Approaches, and Empirical Chapters

The first research question explores the structure of intra-regional (within region) and interregional (extra-region or between regions) collaboration and how the network structure has changed over 11 years (2006-2016). The network structure indicates the degree of dependency of GS countries on GN countries for academic knowledge flows. The following question focuses on the factors (proximities and non-proximities) determining IRC. The last

question is aimed at estimating the effect of knowledge flows on stimulating innovation creation. These will be examined through three different approaches: social network analysis (SNA), gravity model panel data regression, and panel data regression.

3.3 Research Method: Structure of Collaborative Research Network

3.3.1 Data, Collection, Sample and Duration

In order to identify the structure of collaborative research, this study considers co-authored papers indexed by Scopus. International collaboration is defined in this research as a paper authored by scholars from a minimum of two different nations with different authors, for example a paper written by the first author affiliated in an organisation in country A, while the second author is affiliated in another organisation in country B. The number of authors can be more than two. In other words, international collaboration is identified by a minimum of two different countries by the affiliation of the authors. Data were collected from SciVal website[2] and exported in CSV format.

As has been explained in chapter 2 (literature review), this study adopts the concept of a region as a group of countries located close to each other that unite as an intergovernmental organisation and are driven by background similarity (geography, history and economy), common interest and objectives. ASEAN has been selected as the object of study because it represents a region from GS countries. ASEAN consists of ten countries: Indonesia, Malaysia, Singapore, Thailand, Philippines, Vietnam, Brunei Darussalam, Laos, Myanmar and Cambodia. In addition, China is one of the main partners for ASEAN regional collaboration

[2] https://scival.com

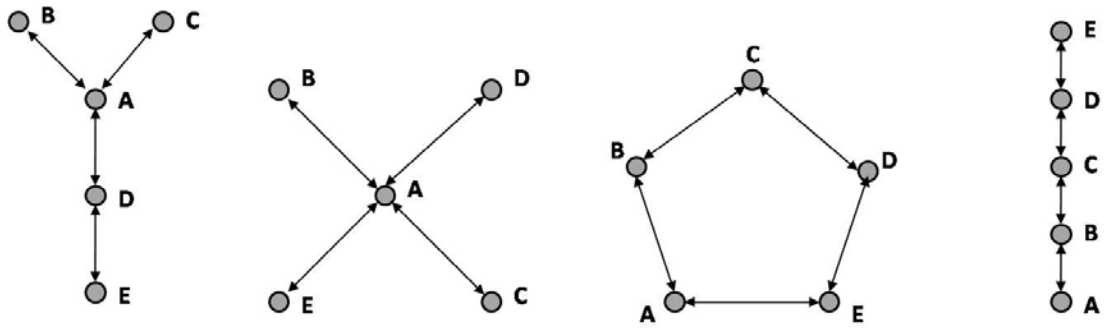
and has been growing as an emerging economy country in GS countries. Therefore, 11 countries are introduced as the sample of this study.

The data time frame of this study is 11 years, starting from 2006 until 2016. ASEAN and China cooperation was formalised into ASEAN plus China in 2006. In the meantime, 2016 was another milestone for ASEAN implementing the ASEAN Community Vision 2025 which was expected to foster integration between ASEAN Member States (AMS) for regional cooperation in politics, economy (trade, investment, manufacture), migration, education and culture, security and disaster dimensions.

3.3.2 Approaches and Measurements

Social Network Analysis (SNA) has been widely applied in various multidisciplinary studies. With no limit to the other subjects, this approach is beneficial to identify knowledge transfer, innovative and research activities (Giuliani, 2005), production networks (Gay and Bernard, 2005), and collaborative research networks (Steiner and Ploder, 2008). This approach can be used to describe interactions among different individuals, organisations and regions (Gluckler and Doreian, 2016). In further analysis, it applies to the identification of the process, mechanism, and communication resolving problems, operating within an institution, managing markets and also personal development (Abbasi, Altmann and Hossain, 2011). SNA also works on performance evaluation and potency, assessment of factors at personal (micro), team, organisation and sub-national (meso), and country level (macro) (Abbasi, Chung and Hossain, 2012). For example, knowledge diffusion among different organisations can be recognised through how the actors perform through research collaboration (Abbasi, Altmann and Hossain, 2011). The greater performance indicates the better knowledge transferred among the organisations.

Social communication among the actors influences network development and determines modelling analysis of the structure within the network (Hou, Kretschmer and Liu, 2008; Ding, 2011; Guns, Liu and Mahbuba, 2011). The study the 'Bavelas-Leavitt Experiment' in 1947 involved different actors and revealed that better performance occurs in 'Star' and 'Y' structures, and a decentralised structure (circle networks) take higher achievement when dealing with more complicated responsibilities (Abbasi, Altmann and Hossain, 2011) (see Figure 2.8). These mean that both local and global communities determine the types of interaction, degree of centrality, betweenness and closeness in various environments (Van Raan, 1998; Lu and Feng, 2009). In a similar context, compound networks apply more complex measurements: eigenvector, diameter, shortest path, distance, clustering coefficient and geodesic (Ding, 2011, p. 187).



Source: (Chung and Liaquat, 2009, p. 36)

Figure 3. 2 Interaction Based on Type of Structures

Conceptually, networks consists of four types: social, information, technological and biological (Lu and Feng, 2009). From a different perspective, networks can be identified based on the type of source of knowledge, (1) contact networks that directly link to origin organisation with information; (2) alliance networks, resulting from intensive and repetitive communication over collaboration or joint ventures among various affiliations to generate innovation (Huggins and

Thompson, 2014). Institutions acquire benefits by utilising knowledge from interaction within networks (Huggins, Johnston and Steffenson, 2008). This means advantages from network are determined by type of knowledge, structure and organisation. Many studies have shown how networks of social, neural, traffic and internet bring various impacts to development and the economy (Ye, Li and Law, 2011). For instance, the intensity of collaborative networks in a co-patenting cluster among 13 regions of 15 in Germany has a strong correlation between economic linkages of regions with top performance in the economy (Bergé, Wanzenböck and Scherngell, 2017). This is also found at the micro level, firms with a central position in the inter-organisational network tend to gain higher performance (Operti and Carnabuci, 2011).

Some advantages can be drawn by applying SNA to identify network structure, such as estimating the relation strength between different nodes (actors), visualising the connection into network diagrams and classifying the hierarchy of the structure. Four measurements have been applied in this study to identify the structure of intra-regional (within region) collaboration and extra-regional collaboration (between ASEAN and China and the rest of the countries), such as: weighted degree centrality, network density, network diversity and community detection.

3.3.2.1 Concept of Network

For more than ten years, networks have been considered in fundamental analysis in spatial economy and geography economics manifested through the quantitative approach (Ter Wal and Boschma, 2009). In the area of geography, networks were initially promoted in 1960 through a geometric concept which was derived from mathematical aspects and elaborated with territory and space views (Glückler and Lazega, 2017). This approach helps to decide the most efficient connection among regions. It has combined with spatial measurement and quantitative

analysis to produce the best decisions to achieve efficiency in terms of effort, time and cost. Some implementations from network analysis may be seen in air transportation systems, railway networks, sea navigation and communication. Unfortunately, this initial concept has a limitation in accommodating qualitative aspects, for example social interactions behind the physical relations cannot be explained by geometric distance. How the actors select either the type of information (knowledge) or collaborative partners is beyond the capability of geometric analysis. Therefore, geographers followed up by developing the concept of network to elaborate quantitative, qualitative and physical aspects.

The concept of the network absorbs abundant perspectives, from qualitative relations (between the collaborators and implementation of communication) to more quantitative and structural aspects (impacts, innovation and growth) (Gluckler and Doreian, 2016). Networks can be applied in various activities like cluster economy, inter-firms connectivity, global cities and migration networks, value chain and international business alliances, and technology and trade activities (Gluckler and Doreian, 2016).

The features of networks can be seen in different forms, centralisation, decentralisation, grouping and path distance (Gluckler and Doreian, 2016). Having a wide range of features, networks in economic geography have a strength to explain the phenomenon of individual characteristics and measure the impact on aggregate levels, for example economic impacts, innovation results and effects of regional competitiveness. It has been interesting to note how networks pledge interdependency connections between place and space; connectivity and the potential to create new knowledge; and knowledge and innovation in regional perspectives. In the meantime, debating the contribution of knowledge networks has grown intensively,

particularly the effect of knowledge through spillover through social form (Quatraro and Usai, 2016).

On the other hand, knowledge networks based on social connectivity are seen as a fundamental factor driving the performance of innovation and economy in a region (Broekel and Boschma, 2012). Joining in the networks allows actors to collaborate and utilise external knowledge to enhance their knowledge capacity (Abramovsky and Simpson, 2011; Balland, 2012; Pratiwi and Suzuki, 2017). In other words , social networks helps to transmit knowledge (Ter Wal and Boschma, 2009). Mathematics and diagrams are widely employed as tools to identify social networks (Ding, 2011). In addition network analysis helps to illustrate the structure of spatial interaction, cluster position and their transformation in the form of mathematics and econometrics analysis (Ter Wal and Boschma, 2009).

Nevertheless, optimising advantages from the network is not based on how the network is formed, but how to manage the network. It is important to manage the flows of knowledge over networks to be more focused (instead of flowing naturally as multi-directions) particularly when it elaborates with internal knowledge to grow innovation aiming for economic advantages (Huggins and Thompson, 2014; Ponomariov and Toivanen, 2014a). Another crucial approach is by selecting knowledge that suits existing knowledge and needs to increase internal capacity. Therefore, these may generate greater advantages from utilising the network.

3.3.2.2 Weighted Degree Centrality

Identifying centrality between nodes has been an essential discussion in network analysis. Being central in the network structure generates three advantages: the central node has the greatest number of ties; it determines the network due to the high dependency of flows from

other nodes; and, is the quickest reaching other nodes. In regard to these three attributes, there are three different measurements to analyse the centrality of nodes: degree, closeness and betweenness (Freeman, 1978). Since this study focuses on collaborative research in ASEAN and China, the rest of the world is represented by a single node.

Nodes in SNA can be formed by individuals or organisations (at micro level), by sub-national regions (at meso level) and countries (at macro level), while ties represent interaction between nodes that may apply to communication, trade and investment, knowledge flows, transportation and the other sectors. Defining the weighted network helps to investigate the differences between nodes that ties not only illustrate either exist or are missing but also the weight (in some forms) attributed to them. The weight of edges in SNA implies a role of frequency, intensity, strength, and duration. In the meantime, for non-social networks, the weight of ties represents capacity or capability.

Weighted Degree Centrality (WDC) is an extended measurement of degree centrality. It is estimated as the total weights of nodes which are directly connected with other nodes and shows the strength of nodes. It can be said WDC calculates the weight of ties (not based on the total number of ties) which is formulated as below:

$$S_i = C_D^W(i) = \sum_j^N W_{ij} \tag{3.1}$$

Where w represents the weighted adjacency matrix, i is defined as the focal nodes, j demonstrates other nodes, N is the total sum of the nodes.

3.3.2.3 Network Density

Network density is defined as the ratio between existing ties to the total number of potential ties (Borgatti and Foster, 2003). It reflects the intensity of knowledge flow between nodes.

Density has a value between 0 and 1, in which 0 represents that there are no ties, meanwhile 1 demonstrates each node is interconnected with all the other nodes (Lowes, Lin and Wang, 2007). Networks with a small number of ties can be called scattered, otherwise a dense network is when the number of the ties reaches close to the maximum. Density is measured by dividing the existing number of ties with the probable number of ties. It can be formalised as follows:

$$ND = \frac{(\Sigma_{rij})}{[(n(n-1))]} \quad (3.2)$$

Where Σ_{rij} is the current connections, while n is the total actors in the network and *ND* is network density.

3.3.2.4 Node Diversity

The measure of diversity has been widely used in various research topics such as innovation, scientometrics, international relations (e.g. geopolitics, geoeconomies and trade), economics and network structure aiming to identify the diversity of the structure in relation to the system. For example, diversity is used to analyse the range of species (ecology science); community structure (social science); structure of exports, investment, assets (economics); variety in research subjects and multidisciplinary research areas (scientometrics); and, creating a new approach from diverse methods of algorithms (computer science) (Guevara, Hartmann and Mendoza, 2016).

Diversity represents equal collaboration among collaborative partners. It is calculated by the total weight of links divided by the total number of links for each node. In the other words, the diversity score of a country is the ratio between the total number of international co-authored papers and total number of collaborative countries. The country diversity score is described as the Shannon entropy of the weights of its links:

$$D(i) = \frac{H(i)}{log(k[i])} \quad (3.3)$$

and

$$H(i) = -\sum(p[i,j])\ log(p[i,j]), j = 1..k[i], \quad (3.4)$$

where

$$p[i,j] = \frac{w[i,j]}{\sum(w[i,j]), l=1...k(i)} \quad (3.5)$$

And k[i] is the total degree of vertex country i, w[i,j] is the weight of the edge(s) between vertices country i and country j.

Diversity of nodes is beneficial to generate innovation from the introduction of different new ideas (Aral and Van Alstyne, 2007). For instance, when a network is constant and rigid with the same collaborators, then similar ideas will circulate between members throughout the time because there is nothing new from the regular collaborators. However, similar to the value of density, diverse networks have a value between 0 (without diversification) and 1 (a perfect diverse network), where 0 indicates that an actor exclusively correlates with other collaborators within its own community and 1 denotes that an actor manages interactions of the same extent with all of the current communities (groups) in the network. A high diversity also implies that a node splits its time more evenly among collaborative ties and between different communities.

3.3.2.5 Community Structure

Another key element in network structure is community structure which displays a characteristic property of the network. Nodes naturally seek similarity from the other nodes to undertake collaboration, particularly with regard to having common goals and similar backgrounds (Bedi and Sharma, 2016b). Community structure presents information on groups or clusters based on hierarchy. Identifying the process of the group or cluster is called community detection.

The concept of community is explained as a group of nodes with a cohesive relationship and having an intensive interaction between nodes. Community detection can be done through similarity or by distance between nodes. There are many types of algorithms for community detection, while Igraph R package offers six different types of algorithms for community detection: edge betweenness, fastgreedy, walktrap, spinglass, leading eigenvector and label propagation. Fastgreedy has been selected in this study for several considerations: 1) it has been widely applied in community detection; 2) it is a bottom-up hierarchical approach; 3) it is able to optimise the function of quality that is called modularity; 4) it provides a quick estimation and method that includes primary approximation due to no parameters to tune.

3.3.3 Data Preparation and Processing of Data

There are several stages to answer the research question. *First* is identifying the countries as the object of study (11 countries) to build a database in SciVal. From the data for each country, there is an option for research collaboration based on year that contains a list of collaborative country partners and the number of collaborations, for example Indonesia and United Kingdom: 30, Indonesia and Germany: 15. Furthermore, this selection was exported in CSV format. After all the data co-authored publications have been downloaded, the following stage is creating an adjacency matrix in RStudio (as the software for data manipulation). *Second*, the adjacency matrixes are distinguished into intra-regional collaboration (between ASEAN Member States-AMS and China) and extra-regional collaboration (between AMS and China and the rest of the world). In order to have an adjacency matrix for extra-regional collaboration, matrix cell collaborative research (*ij*) between non-ASEAN plus China and the other country partners was denoted as 0 in regard to unavailability of data (as the focus of study is ASEAN plus China). *Third*, these adjacency matrixes were then processed using particular packages

from i-graph in RStudio for four main measurements such as WDC, network density, node diversity and community structure.

3.4 Research Method: Determinant Factors Undertaking IRC

3.4.1 Data, Collection, Sample and Duration

The data on international co-authored publications are extracted from SciVal for a duration of 11 years (2006–2016) with a total of 1,584 collaborations of data panel. Co-authored publications represent collaborative research as a dependent variable. Independent variables consist of country size, geographical proximity, non-spatial proximities, and economic relations. All of these variables are secondary data collected from particular different websites (see Table 3.1).

Table 2. 3 Data Description of Determinant Factors of IRC

Variable	Estimated by	Duration	Sources
Collaborative research	International co-authored publications	11 years	SciVal from Scopus
Country Characteristics	Scholarly outputs	11 years	Scopus
	Gross Domestic Product (GDP) per capita	11 years	The World Bank
	Population density	11 years	The World Bank
Geographical proximity	Geodesic distance		CEPII research and expertise on the world economy
Non-spatial proximities	Historical relation through colonialism and imperialism		CEPII research and expertise on the world economy, national website from each country
	Culture or language similarity		CEPII research and expertise on the world Economy
	Membership ASEAN+3		ASEAN Secretariat
Economic relation	International trade flow	11 years	International Trade Centre

Source: author

3.4.2 Approaches and Measurements

The gravity model has been broadly utilised to identify a spatial interaction model that analyses connectivity or interaction between two different areas (Ponds, van Oort and Frenken, 2007b), for example identifying economy activities (such as trade, investment, migration), transportation, information and communication flows (Anderson, 2010; Hoekman, Frenken and Tijssen, 2010c). The model has some strengths to identify the character relationship between the two countries and capture their behaviours regarding cooperation; the ability to elaborates an immense observed diversity in the interaction across nations; and generates the most apparent and vigorous empirical evidence in regional interaction (Anderson, 2010; Mele and Baistrocchi, 2012). This model has successfully been proven to describe bilateral relations between two countries, for instance international trade rising because of stronger economic performance, and declining as farther distance appears between them (Picci, 2009). The gravitational force between two countries is presumed to be dependent on the mass of the countries and gap in the distance between them (Isard, 1956; Hoekman, Frenken and Van Oort, 2009).

This implies the intensity of international research collaboration between ASEAN countries and China with the rest of the world is hypothesised to be dependent on their publication activities and country capacity, and inversely dependent on the spatial distance between them. Estimating collaborative research differs from the common gravity model applications as co-authored paper does not have direction (Montobbio and Sterzi, 2013). As a consequence, the countries' origin and countries' destination are named with the countries' host (*i*) and countries' partners (*j*).

In the meantime, the gravity model provides an appropriate explanation for two countries' interaction and the strength of flow between them; some critics are brought to respond to the model. *First*, the distance measurements will bring different effects on the intensity relation, either employ functional distance or physical distance (Albert, 2020). Physical distance generally estimates as a straight-line (Euclidean distance), which has the shortest possible path between two nodes and can be selected assuming no constraints. Functional distance is attributed to transportation modes such as roads, rail, sea, and air. Estimating functional distance would differ regarding the political border, cost, and natural conditions (safety). Internalising distance into an equation with an assumption ignoring political and spatial geography needs to be blend since these have distinct borderline. Hence, this may bring a non-linear effect.

Second, determining the masses included in the basic Newton's formula is the most crucial challenge (Mele and Baistrocchi, 2012). Therefore, it requires an abundant variety of data that can be customised regarding the study's need. The radiation model can be an alternative method, particularly in estimating population density and accommodating Linder's assumption (Jian, 2011; Mele and Baistrocchi, 2012).

Third, a relation intensity is not presented in units due to the units from estimation has no physical meaning. Elaborating a gravitational constant into the Newtonian gravity model is aiming to produce the physical estimation meaning. Meanwhile, the model is unsuccessful to give an explanation for the adaptation of a gravitational constant into the estimation (Mele and Baistrocchi, 2012). For that reason, some opinions disagree since it has not been academically confirmable and mostly identify through observation (Albert, 2020)

Fourth is an aggregation bias because of differing trade costs and differing trade elasticities regarding the costs. Also, specification bias occurs due to a variable associated with gross trade flows contributing to added value creation in GDP (Anderson and Yotov, 2010). However, this problem can be addressed using suitable sectoral output and expense variables (Anderson, 2010).

Fifth, the traditional gravity model eliminates multilateral resistance leading to omitted variable bias (Anderson, 2010). Multilateral resistance demonstrates a little correlation with the index of remoteness, while omitted variable will correlate with the other variables in the right-hand side of regression, and therefore bias estimation (Anderson and Yotov, 2010). The country fixed effect seems pertinent to address the issue.

3.4.3 Model Specification

The determinants of ASEAN plus China's international research collaboration are modelled in an analogy to Newton's law. Gravity models are mathematically written as follows:

$$Y_{ij} = X_{ij} + \varepsilon_{ij} \qquad i, j = 1, \dots \dots, n \tag{3.6}$$

Where Y_{ij} is assumed to be a stochastic dependent variable regarding observed international collaboration with $\gamma_{ij} \geq 0$ between two countries i and j estimated by the number of international co-authored papers. Meanwhile X_{ij} is a function described as a relationship between dependent variables to independent variables, say μ_{ij}, with $E[Y_{ij}] = \mu_{ij}$. Moreover, ε_{ij} is explained as a disturbance term and followed with property $E[Y_{ij}|\gamma_{ij}] = 0$.

The model is further developed to explain the empirical analysis using part of model X_{ij}. Since international collaboration involves interactions between countries in a multi-country setting,

the gravity type model of spatial interaction is the suitable instrument. Therefore, $\mu_{ij} = X_{ij}$ is devoted as a covariates function to measure the characteristics of the origin countries, destination countries, and the separation between them, set by:

$$X_{ij} = A_i B_j f(S_{ij}) \qquad i, j = 1, \dots \dots, n \tag{3.7}$$

Where O_{it} is a function of characteristic country *i* of interaction in year *t*; D_{jt} is a function of characteristic country *j* of interaction in year *t*; and S_{ij} is a function of the characteristic of the separation between two countries *i* and *j*. α_1 and α_2 are the respective parameters to be estimated.

$$O_i = o_{it}^{\alpha_1} \qquad i = 1, \dots, n; \;\; t = 1, .., 11 \tag{3.8}$$

$$D_j = d_{jt}^{\alpha_2} \qquad j = 1, \dots, n; \; t = 1, \dots, 11 \tag{3.9}$$

The character of the country is represented by the size of density (population/km^2), income per capita (GDP/population) and academic capacity through the number of international publications in country *i* and country *j* in year *t*. These variables are indicated affecting the countries to have close relationships between them. The focus of interest is on the geographical separation function S_{ij}, which is specified as:

$$S_{ij} = exp\left[\sum_{k=1}^{K} \beta_k \, s_{ij}^{(k)}\right] \qquad i, j = 1, \dots \dots, n; \; k = 1, \dots, 5; \;\; t = 1, \dots, 11 \tag{3.10}$$

Where $s_{ij}^{(k)}$ demonstrates a measure of separation between country *i* and country *j*. The β_k is the unknown parameter. Separation measures are explained below:

- $s_{ij}^{(1)}$ denotes geographical distance between the capital cities of country *i* and country *j* as a pair of collaboration measures in km.
- $s_{ij}^{(2)}$ is dummy variable that is set to one if two countries *i* and *j* have historical relations through colonialism, and zero otherwise.

- $s_{ij}^{(3)}$ is dummy variable that is set to one if two countries *i* and *j* have a similar culture or language, and zero otherwise.
- $s_{ij}^{(4)}$ is dummy variable that is set to one if two countries *i* and *j* are bounded formally within a regional organisation such as ASEAN plus China, and zero otherwise.
- $s_{ij}^{(5)}$ denotes international trade flow between country *i* and country *j* measured in value of million US$. International trade functions as the control variable between country *i* and country *j*.

Integrating equations (8) – (10) into equation (7) leads to the empirical model:

$$Y_{ijt} = \alpha_0 + o_{it}^{\alpha_1} d_{jt}^{\alpha_2} exp\left[\sum_{k=1}^{K} \beta_k s_{ijt}^{(k)}\right] + \varepsilon_{ijt} \qquad i, j = 1, \dots\dots, n \; k = 1,.., 5; \; t = 1,.., 11 \quad (3.11)$$

The equation that will be estimated is:

$$\gamma ln\text{TCP}_{ijt} = \beta_0 + \beta_1 ln\text{PUB}_{it} + \beta_2 ln\text{PUB}_{jt} + \beta_3 ln\text{POP}_{it} + \beta_4 ln\text{POP}_{jt} + \beta_5 ln\text{GDPC}_{it} + \beta_6 ln\text{GDPC}_{jt} + \beta_7 ln\text{DST}_{ij} + \beta_8 \text{DLANG}_{ij} + \beta_9 \text{DCOL}_{ij} + \beta_{10} \text{DMEM}_{ij} + \beta_{11} ln\text{TRD}_{\text{ij}} + \mu_i + \mu_j + \mu_t + \varepsilon_{ijt} \quad (3.12)$$

Where: $\gamma ln\text{TCP}_{ijt}$ is the total number of co-authored papers for countries *ij* for years *t*; $\beta_1 ln\text{PUB}_{it}$ as total scholarly outputs or academic publications for country *i* for years *t*; $\beta_2 ln\text{PUB}_{jt}$ as total academic publications for country *j* years *t*; $\beta_3 ln\text{POP}_{it}$ as total population of country *i for* years *t;* $\beta_4 ln\text{POP}_{jt}$ as total population of country *j for* years *t*; $\beta_5 ln\text{GDPC}_{it}$ as GDP per capita of country *i* for years *t;* $\beta_6 ln\text{GDPC}_{jt}$ as GDP per capita of country *j* for years *t*; $\beta_7 ln\text{DST}_{ij}$ is geodesic distance between countries *ij*; $\beta_8 \text{DLANG}_{ij}$ is dummy language similarity for countries *ij*; $\beta_9 \text{DCOL}_{ij}$ is dummy colonial ties for countries *ij* as proxy of historical relations; $\beta_{10} \text{DMEM}_{ij}$ is dummy for membership in ASEAN plus three; $\beta_{11} ln\text{TRD}_{\text{ij}}$ volume of international trade between countries *ij* for years *t*; μ_i and μ_j as dummy country *i* and dummy country *j*; μ_t as dummy of Year and; ε_{ijt} as error terms.

Since the dependent variable $\gamma ln\text{TCP}_{ijt}$ (the total number of co-authored papers) is count data, the parameters of equation (7) cannot be estimated by ordinary least square (OLS) regression. The basic model found through the Poisson regression and Negative Binomial are appropriate to handle count data (Hausman, Hall and Griliches, 1984; Beck and Tolnay, 1995) and it is widely considered to be a reasonable description for non-negative integer values (Maddala, 1983). Country and year fixed effects have been introduced into the model to address unobserved time-invariant country characteristics and yearly changes in research publications.

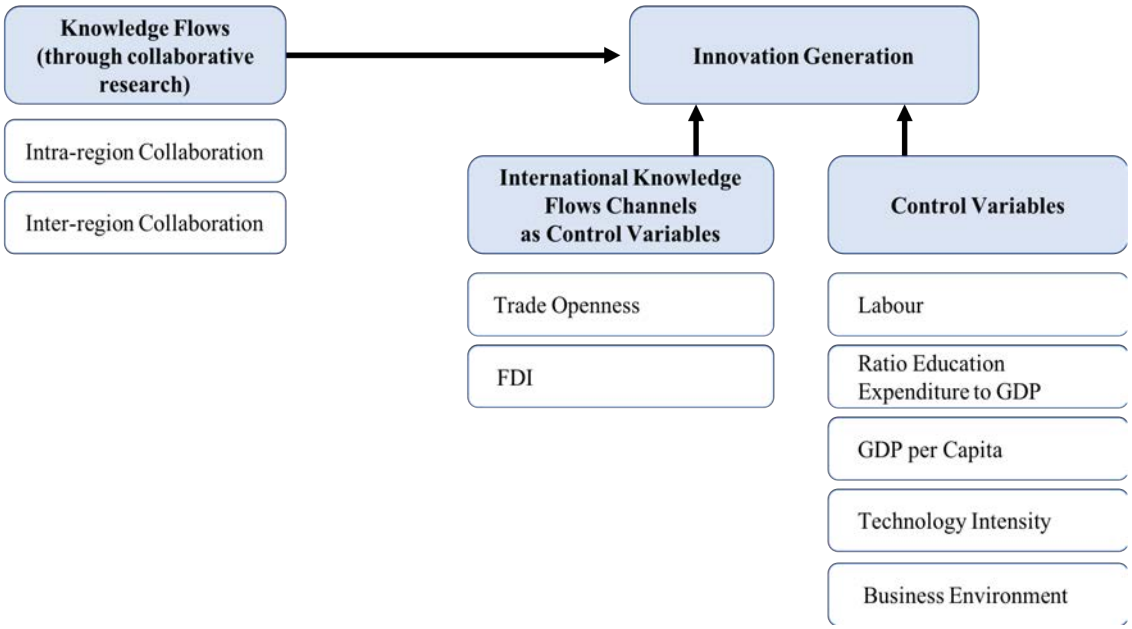
3.5 Research Method: Effect of Knowledge Flows on Innovation Generation

3.5.1 Data, Collection, Sample and Duration

The main objective of this study is to investigate whether knowledge flow brings advantages to grow innovation capacity at the country level, along with other factors such as international relations (as the other transmissions of knowledge flow), country size (labour and GDP per capita), R&D intensity and education quality. The result will not be interpreted as a causal relation.

The dependent variable in this study is innovation performance which is measured by patents. Patents are able to document innovation (Griliches, 1990a; Alca and Gittelman, 2006), and the most operational innovation that is ready for implementation in productive sectors, like manufacturing or industries (Griliches, 1990b; Bloom and Van Reenen, 2002). In addition, this measurement is relevant and reliable to capture innovation performance both at micro and macro scale which usually involves diverse and dynamic data (Hagedoorn and Cloodt, 2003). Since unit analysis of this study is at country level, these measurements represent macro

analysis. Patents data were obtained from the statistics of the World Intellectual Property Organization (WIPO).



Source: Author

Figure 3. 3 Research framework impact knowledge flows on innovation performance

Furthermore, independent variables are collaborative research. Collaborative research is distinguished between intra-regional collaboration (within region) and interregional collaboration (outside region) (De Noni, Ganzaroli and Orsi, 2017). Collaborative research in this thesis is estimated using numbers of co-authored publications refer to the previous studies (Melin and Persson, 1996; Sutter and Kocher, 2004; Leydesdorff and Wagner, 2008; Lemarchand, 2012) which were retrieved from Scopus data base through SciVal website.

In addition, control variables which were obtained from various sources are included in the model. Accommodating factors of international relations and international experience, international trade and foreign direct investment (FDI) have been elaborated into the model.

Trade openness is the ratio between the total value of exports and imports divided by the total GDP, reflecting the country openness for international relations. In addition, external components like technologies, equipment and machinery, and raw material which are obtained through international trade or FDI, are needed to generate innovation. Technological intensity is measured through the ratio of R&D investment to GDP which represents the country's efforts to obtain external knowledge (Tsai, 2009). The size of the country is estimated using the size of labour and GDP per capita. GDP per capita represents economy level or wealth of country leading to the capacity to finance development, including R&D activities (Dall'erba and Le Gallo, 2008; Orsi, Belussi and De Noni, 2018).

Table 2. 4 Data description of impact of knowledge flows on innovation performance (2006-2016)

Elements	Variables	Duration (years)	Sources
Innovation performance	Patents	11	World Intellectual Property Organization (WIPO)
Knowledge flows	International co-authored papers within region (ASEAN and China)	11	SciVal from Scopus
	International co-authored papers extra-region (between ASEAN and China with non-ASEAN)	11	SciVal from Scopus
International flows	• Trade openness	11	International Trade Centre
	• FDI inflow	11	The World Bank
R&D intensity	Ratio R&D spending to GDP	11	Country statistics, Financial Reports from Country' ministry, The World Bank
Country size	• Labour	11	The World Bank
	• GDP per Capita	11	The World Bank
Labour quality	Ratio education spending to GDP		Country statistics, Financial Reports from Country' ministry, The World Bank
Government policy	Ease doing business score	11	The World Bank

Sourced: author

In addition, the quality of labour (as input for the knowledge production model) assumes an influence over knowledge creation and innovation which is represented by the education spending ratio to GDP (Lee, Florida and Gates, 2010). This variable is a proxy for previous knowledge which is essential to acquire external knowledge. The business environment is a proxy of the government policy to support business due to patents that are closely associated with business entities (De Noni, Ganzaroli and Orsi, 2017; Orsi, Belussi and De Noni, 2018). There are 99 observations on nine countries located in the Southeast Asia region (Brunei Darussalam, Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, Viet Nam) and China over a duration of 11 years (2006-2016). Laos and Myanmar are not included as research sampled due to data being unavailable. China was included in the analysis as a leading Global South and Asian country.

3.5.2 Approaches and Measurements

The main objective of this chapter is to measure the impact research collaboration and innovation performance based on a panel data set. Panel data have the ability to capture the various characteristics among individual observations (countries in this case) that appear constant and not constant over the period under study (Jalles, 2010). Using panel data offers several advantages: it is able to cover a greater amount of information, data variation, low potential collinearity among variables, increase the degree of freedom, and more, is efficient in estimating the model (Hsiao, 1986). More diverse data has lowered collinearity in a model that uses distributed lags. In addition, using panel data helps to adjust the data dynamics leading to efficiency in analysis (Baltagi, 1996). In the other words, a panel data set can cope with individual behaviour that may be difficult to identify by cross section or a time series data set. With heterogeneity of information, a panel data set collects more information from the

observations. Furthermore, fixed and random effects can be distinguished using a panel data set which is beneficial to use in describing an immense and comprehensive sample or predicting individual behaviour (Wooldridge, 2001). Using fixed effects brings another consequence to manage greater coefficient variation of individuals or the period observation (Jalles, 2010), while random effects presumes the behaviour of period observations and the sample are either unknown or non-measurable (Baltagi, 1996). This study will use fixed effects panel data regression for two considerations: 1) panel data expands the total number of observations; and 2) controlling the model from annual effect dynamics. In addition, to partially address endogeneity, one-year lagged independent variables have been elaborated into the model estimation.

3.5.3 Model Specification

In order to measure the innovation performance as an impact from research collaboration, the study used the proposed basic model as follows:

$$\gamma ln\,\mathrm{PTN}_{it} = \beta_0 + \beta_1\, ln\,\mathrm{INTRA}_{it} + \beta_2\, ln\,\mathrm{EXTRA}_{it} + \beta_3\mathrm{TRDr}_{it} + \beta_4\mathrm{EDUr}_{it} + \beta_5\mathrm{R\&Dr}_{it} + \beta_6\, ln\,\mathrm{FDI}_{it} + \beta_7\, ln\,\mathrm{LAB}_{it} + \beta_8\, ln\,\mathrm{GDPc}_{it} + \beta_9\, ln\,\mathrm{BUSenv}_{it} + \mu_i + \mu_t + \varepsilon_{it} \quad (3.13)$$

Where $\gamma ln\,\mathrm{PTN}_{it\iota}$ is the total number of patents for country *i*; $\beta_1\, ln\,\mathrm{INTRA}_{it}$ is the total number of intra-regional co-authored papers for country *i;* $\beta_2\, ln\,\mathrm{EXTRA}_{it}$ is the total number of interregional co-authored papers for country *i*; $\beta_3\mathrm{TRDr}_{it}$ is the ratio of total trade value to total GDP country of *i*; $\beta_4\mathrm{EDUr}_{it\iota}$ is the ratio of total education spending to total GDP for country *i*; $\beta_5\mathrm{R\&Dr}_{it}$ is the ratio of total R&D spending to total GDP country for $i\beta_6\, ln\,\mathrm{FDI}_{it}$ is the total volume of FDI inflow for country *i*; $\beta_7 ln\mathrm{LAB}_{it}$ is total labour force of country *i*; $\beta_8 ln\mathrm{GDPc}_{it}$ is total value of GDP per capita for country *i*; $\beta_9 ln\mathrm{BUSenv}_{it}$ is ease of doing business score as proxy of government policy supporting business environment of country *i*; μ_i is dummy for

country fixed effect; μ_t is dummy for year fixed effect; and ε_{it} is error term. While *i* represents the country and *t* the time for the period 2006–2016.

In addition, the specification model with one-year lagged is proposed as follows:

$$\gamma ln\,\mathrm{PTN}_{it} = \beta_0 + \beta_1\, ln\,\mathrm{INTRA}_{it-1} + \beta_2\, ln\,\mathrm{EXTRA}_{it-1} + \beta_3 \mathrm{TRDr}_{it-1} + \beta_4 \mathrm{EDUr}_{it-1} + \beta_5 \mathrm{R\&Dr}_{it-1} + \beta_6\, ln\,\mathrm{FDI}_{it-1} + \beta_7\, ln\,\mathrm{LAB}_{it-1} + \beta_8\, ln\,\mathrm{GDPc}_{it-1} + \beta_9\, ln\,\mathrm{BUSenv}_{it-1} + \mu_i + \mu_t + \varepsilon_{it} \quad (3.14)$$

CHAPTER IV
THE STRUCTURE OF INTERNATIONAL COLLABORATIVE RESEARCH OF ASEAN COUNTRIES AND CHINA

4.1 Introduction

Studies about international collaborative research have been increasingly growing in the GN countries where academic knowledge and research performance are well established. In addition, GN countries generally have high-income economies that are conducive for research and academic activities. A wide range of topics have been studied, starting from motivation to the structure and impact of collaborative research. GS countries have economies with limited incomes, unstable political and security conditions and a low quality of human resources which produce in less developed academic and research performance. As a result, most of the literature in the area of collaborative research has been dominated by GN countries' perspectives and demonstrates how GS countries depend on GN countries for knowledge flows and whether it is carried out at micro level (individual, institutions), meso level (cities or sub-national) and macro level (countries). In addition, there is a need to identify the structure of international collaboration in research in the GS countries to strengthen the knowledge production literatures from the perspective of GS countries, particularly from the regional level (as a group of countries) in Southeast Asia.

This chapter aims to analyse the structure of extra-region collaboration (research conducted beyond the region). A region is determined as a group of countries with similar spatial, social, cultural, historical and political characteristics which bring interdependency between countries and formalise an identity that is accepted by global communities. This identity is formed

through social and political constructions that are generally manifested formally in an organisation that bounds the members into an intergovernmental relation.

A pattern of international collaboration may be discerned in the hierarchy of international collaboration ASEAN and China with the rest of the world. In addition, the findings from this chapter will provide the baseline to analyse the following chapters, such as the determinant factors for international collaboration (chapter 5) and its correlation to innovation performance (chapter 6). There are five sections within this chapter. The first section discusses the ASEAN and China, explaining its history and its relation to China, and researchers' performance in academic publications for co-authored papers and single-authored papers. The following sections will explore the structure of international collaborative research extra-region collaborations; network density; community detection; and finally, present the concluding discussion.

4.2 ASEAN and China: Historical Relations and Publication Structure

Three countries (the Philippines, Federation of Malaya and Thailand) on 31st July 1961, formed an organisation called the Association of Southeast Asia (ASA). This later officially crystallised into the Association of Southeast Asian Nations (ASEAN) on 8th August 1967 in Bangkok, by a new grouping of five countries: Indonesia, Malaysia, the Philippines, Singapore and Thailand. As an intergovernmental organisation at regional level, ASEAN means to accommodate the voices of developing countries, particularly in achieving stability in politics and security; and implement peace and cooperation in the region. Since the beginning, ASEAN promotes discussion, cooperation and provides resolution to overcome issues which potentially impact on stabilisation in the region.

The organisation grew continuously. Brunei Darussalam joined on 8th January 1984, and the organisation became known as ASEAN-6. The collapse of Communism in Eastern Europe and the end of the Cold War resulted in more relaxed cooperation between ASEAN and neighbouring Communist countries like Vietnam, Cambodia and Laos. This brought significant impacts on ASEAN expansion by the addition of Vietnam (28th July 1985), Laos and Myanmar (23rd July 1997) and Cambodia (30th April 1999). The additional countries completed ASEAN, resulting in ten countries in the organisation and widened cooperation among members, not only in geopolitics and security (military) but also in the economy, education, sociocultural, agriculture, industry, and research and development. Cooperation within ASEAN manifested through collaboration and mutual assistance for particular cooperation on common interests (such as education), accelerating and modernisation of agricultural development (since agriculture is the prime sector for the economy in most country members at the moment), and increasing industrial productivity by new equipment and innovation.

ASEAN is one of the most dynamic regions in the world. Located at the heart of the Asia Pacific region, ASEAN is home for 635.9 million inhabitants (i.e. 8.5% of the world population in 2016) and a combined GDP of $ 2.57 trillion (3.4% of the total world GDP). The ASEAN economy is placed as the sixth largest economy in the world and the third largest in Asia with capital markets estimated at $ 3.7 trillion. The economy within this region has continuously grown beyond 5% annually during the last ten years. In the meantime, since a slowing economy has occurred in neighbouring countries (India and China), global investment has shifted to this region and it has responded by an accelerating regional economic integration since 2015 and will be finalised in 2025.

Meanwhile, ASEAN countries have increased investment in the science and technology sector. The impact of investment in science and technology can be measured with two essential indicators: 1) publications as a direct result from research and development and; 2) innovation as further outcomes from research and publications. Academic research is strongly needed to boost economic growth and improve the quality of life, particularly using new knowledge creation and technological invention.

Scientific publications usually are well documented through peer-reviewed academic journals. More than 100,000 journals exist in the world with various ranges of quality. Indexing helps to identify journal quality and sort out journals based on the quality. The Institute of Scientific Information or ISI (known as well as Thomson ISI) and Scopus are two reputable journal databases which are broadly accepted in scientific societies. Scopus has the strength to cover titles from all geographical regions, including non-English titles, even though abstracts should be written in English and provided with the full article. From the Scopus data base, more than 22% of titles are published in non-English, and include 40 different local languages. It can be said that using data from Scopus can closely represent the actual condition of international publications made by many countries, while this indexing capacity may be a limited undertaking by other providers.

4.2.1 The Performance of ASEAN And China in Academic Publications

The numbers of academic papers authored by ASEAN scholars published in journals indexed by Scopus have risen more than fourteen times from 6,641 publications in 1996 to 98,568 in 2017 (see Table 4.1). With the growth of publications an average 13.87% per year, ASEAN has contributed 6.18% of the total Asia Pacific regions or 1.8% of world publications during the past 21 years. In the meantime, China recently has shown a remarkable growth in producing

publications at an increase of more than fifteen times compared to 1996 and has contributed 40.4% of Asia Pacific regions or 11.79%of total global publications. However, although ASEAN and China have slight differences in the annual growth of publications, it can be advised that China produced many more publications than ASEAN at more than fifteen times the total ASEAN publications.

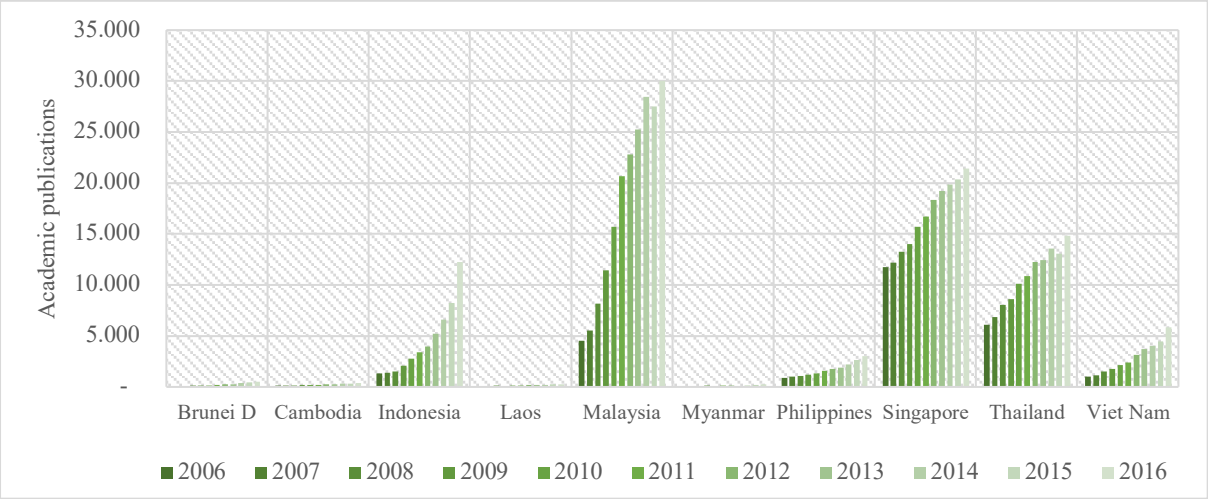
Table 4. 1 Number of publications in ASEAN, China, Asia Pacific and World

Year	ASEAN	China	Asia Pacific	World
1996	6,641	33,731	209,997	1,181,259
1997	7,848	37,114	224,023	1,209,154
1998	8,216	43,310	234,530	1,222,922
1999	9,502	44,130	44,458	1,231,790
2000	11,558	52,590	263,788	1,302,949
2001	11,460	66,729	284,315	1,412,525
2002	13,377	69,239	298,046	1,482,533
2003	16,078	82,674	333,008	1,556,300
2004	18,935	118,041	387,726	1,670,302
2005	22,201	172,118	477,994	1,896,489
2006	25,301	199,241	529,786	1,994,161
2007	27,743	227,509	577,363	2,117,525
2008	33,254	265,690	635,927	2,216,034
2009	38,647	310,249	704,486	2,323,438
2010	46,923	346,575	774,974	2,453,818
2011	54,760	396,513	866,533	2,608,685
2012	61,065	416,074	914,410	2,735,723
2013	66,538	456,866	979,352	2,837,258
2014	73,223	489,565	1,030,005	2,892,432
2015	74,733	458,733	999,000	2,852,873
2016	85,597	495,663	1,065,863	2,921,862
2017	98,568	531,035	1,115,249	2,962,576
Overall	812,168	5,313,389	13,150,833	45,082,608

Sourced: (SciVal, 2018b)

Narrowing to focus on ASEAN members' performance in publication, three main groups of countries may be classified, based on their annual academic outputs: high, medium and low. Malaysia has been the most productive country on publications which can produce more than 200,000 papers during 2006-2016. The rate of publication is supported with a continuously remarkable growth that accounted an average 21.89% which has successfully elevated their annual outputs more than six times from 4,518 publications (in 2006) to 30,050 publications (2016) (Figure 4.1). The other prominent countries are Singapore and Thailand who have

similar trends on consistently positive growth with an average 6.24% and 9.46% respectively and resulted in total publications of 182,878 and 116,818 in 2016. Singapore used to be the country with the highest publications in ASEAN until 2011 when Malaysia overtook Singapore's annual publications.



Sourced: SciVal 2018

Figure 4. 1 Academic outputs of ASEAN countries

In the medium group of annual academic outputs, there are Indonesia, Vietnam and the Philippines. Indonesia has experienced an outstanding growth counted at 25.59% per year with the highest growth occurring in 2016 at 49.73%. The impact on annual scholarly outputs in 2016 is more than nine times greater (12,284 publications) compared to at the beginning of the period – in 2006 (for 1,324 publications). A similar trend has happened in Vietnam where their publications grew consistently at 19.81% per year. The rest of the countries are included in the lowest annual publications group since their scholarly outputs are less than 600 publications per year. Myanmar is the country with the least annual publication which has numbered 1446 total publications during 11 years (2006-2016). This was followed by Laos (1764 publications), Cambodia (2554 publications) and Brunei Darussalam (2556 publications).

4.2.2 The Structure of Academic Publications in ASEAN and China

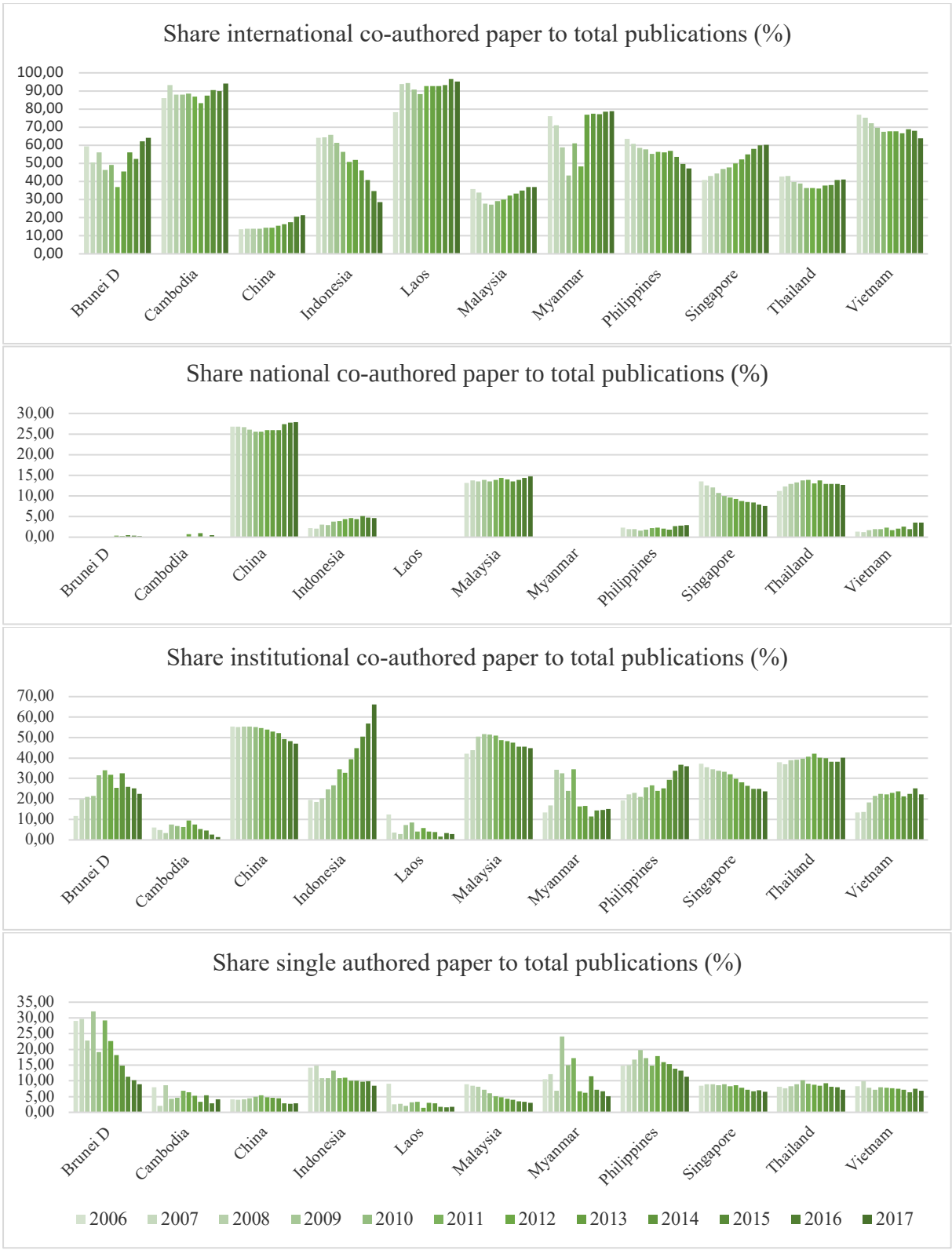
Furthermore, based on the type of authorship, scholarly outputs are generally documented by two main categories, single-authored paper and co-authored papers. Co-authored papers consist of three different classifications: 1) institutional collaboration in which the paper is co-authored by scholars within the same institution; 2) national collaboration – a paper co-authored by several scholars from different institutions within a nation and; 3) international collaboration – a paper co-authored by scholars from a minimum of two or more different countries. Therefore, the structure of publication of a country can be identified from four classifications.

Academic publications from 11 countries have shown a diverse structure based on the type of paper authorship as presented in figure 4.2. International co-authored papers generally have been the backbone of the publication structure for most countries, like Brunei Darussalam, Cambodia, Laos, Myanmar, Philippines, Singapore, Thailand and Vietnam, contributing more than 40% from of the total scholarly outputs. Cambodia and Laos have the highest proportion of international co-authored papers accounting averagely 91.72% and 88.73% respectively. China, Singapore and Malaysia have experienced positive trends in contributing to this category, while other countries underwent negative proportion trends, particularly Indonesia (-7.54%), Philippines (-2.87%) and Vietnam (-1.80%).

Institutional co-authored papers are the following highest numbers out of total publications. With a contribution of more than 20%, at least seven countries rely on this category to support their publications beside international co-authored papers. China has been the highest provider of institutional co-authored papers accounting for 53.42% annually, followed by Malaysia (47.85%) and Thailand (39.24%). In the meantime, Indonesia has the most remarkable growth

contribution (accounting for 11.72% annually), from 19.64% in 2006, which increased to 56.85% in 2016. Another positive growth on contributions was also seen from the Philippines and Vietnam. On the other hand, although China recorded the highest contribution of institutional co-authored papers, their contribution has decreased gradually at -1.36% per year. Similarly, Singapore with an average shared 31.01% has experienced negative growth over the period (-3.90% per year).

In another category, national co-authored papers are not really popular for certain countries since they have very small contributions to this category, accounting for less than four papers (Brunei Darussalam and Cambodia) or even without any publications in this category (Laos and Myanmar). In contrast, in the other countries, the national co-authored paper category gives valuable shared total publications, for instance China (an average of 26.40%), Malaysia (13.81%), Thailand (12.98%) and Singapore (10.11%) although the contribution continuously declined at -3.90% per year. Meanwhile Indonesia and Vietnam show positive trend contributions (9.03% and 11.63%) even though they have small average contributions (3.74% and 2.15% individually).



Sourced: author

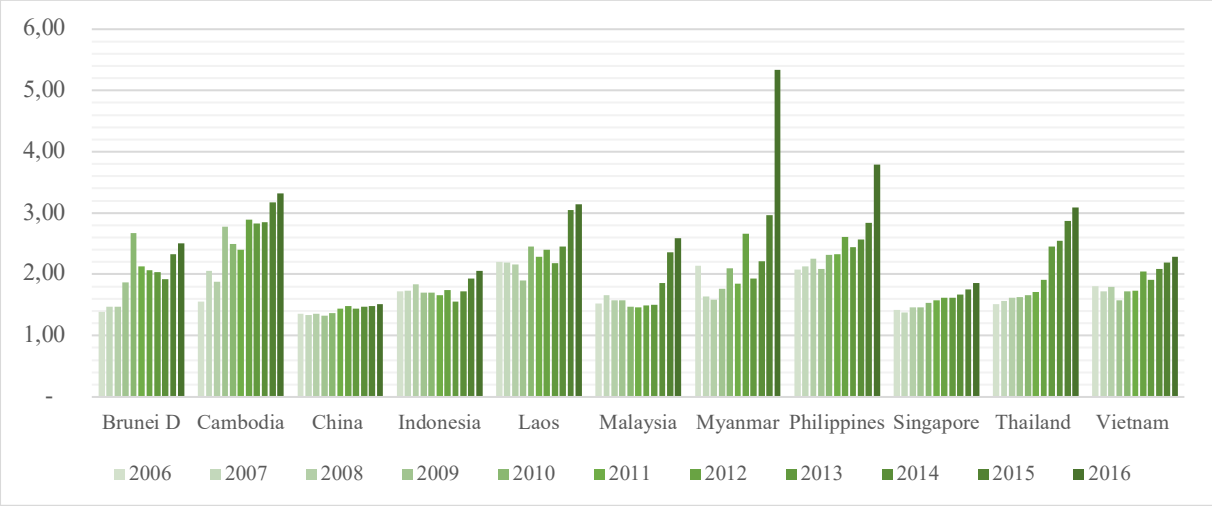
Figure 4. 2 Structure of publication based on category of authored papers

Another category is the single-authored paper in which eight countries have limited contributions (less than 10%) with negative growth for this group. For instance, Malaysia with a 5.8% share to total publication has experienced annual negative growth of -9.01%. In addition, Brunei has experienced significant declining contributions from 29.7% (in 2007) to 10.13% (in 2016).

A greater contribution of co-authored papers (including international, national and institutional) than single-authored papers representing collaboration has been desired by most of the countries for particular intentions. In addition, this indication is strengthened by a continuous positive growth of co-authored papers over the study period. It can be said collaboration through co-authored publications has been considered as an essential mechanism for knowledge flows. Among the three types of co-authored papers, the international category offers greater opportunity to acquire external knowledge from global scholars compared to the other two categories. Undertaking international collaboration with researchers from abroad not only facilitates the acquisition of new knowledge from external sources but also shares current trends in research and higher education occurring worldwide, for example the internationalisation of higher education institutions through advanced research, and the latest innovation as a result of research and development. Therefore, international co-authored publications help a country to respond to global dynamics through academic approaches.

International co-authored papers involve domestic scholars and scholars from at least one different country abroad. Identifying how many countries have collaborated with the country of origin for every paper published is crucial since the number of collaborative countries represents a degree of international collaboration (Olmeda-Gómez *et al.*, 2014). The greater

the number of country partners collaborating on every one co-authored paper provides a higher degree of international collaboration.



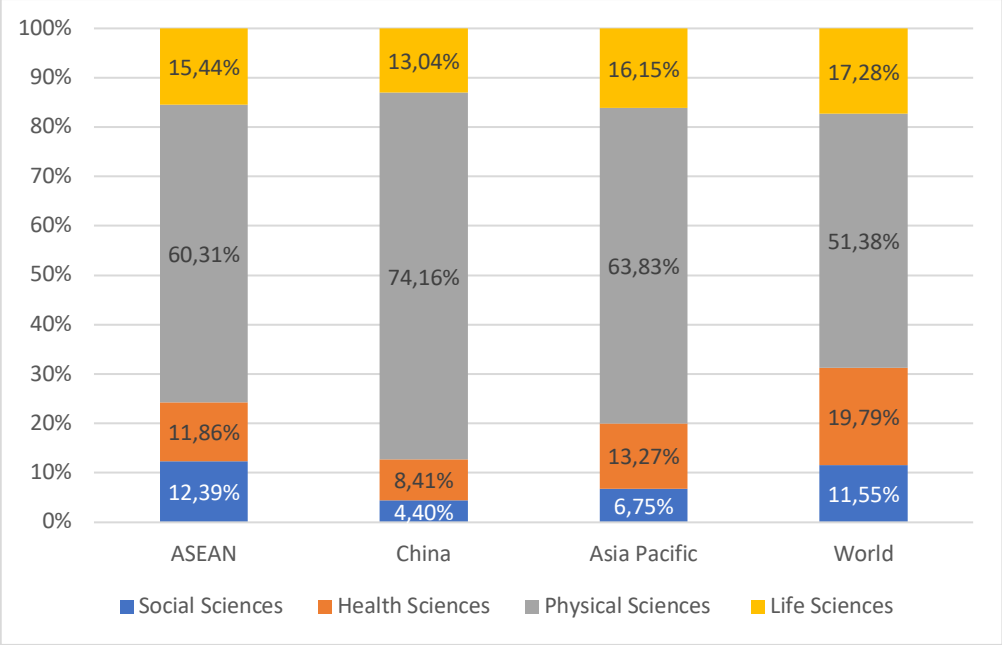
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Figure 4. 3 Average number collaborative country partners per co-authored paper

As shown by Figure 4.3, most countries on average have more than one collaborative country partner for each co-authored paper, meanwhile the number of collaborative countries continuously grows during the period. Several countries have collaborated with two countries, like Brunei Darussalam, Malaysia and Vietnam, while the other countries in the rest of the period collaborated with more than three countries such as Cambodia, Laos, Myanmar, Philippines, and Thailand. Among 11 countries, Myanmar is recorded as a country with the highest number of collaborative country partners (five countries) for every international co-authored paper although it only occurred once in 2016 by rocketing to 80.53% from 2015. Meanwhile, in the same year, Myanmar only produced 226 international co-authored papers, which was an increase of 47.71% from 153 papers in 2015. This demonstrates an intensive international collaboration with several collaborative countries, but in a small number of co-authored papers since international co-authored papers have been main contribution (78. 75%) of the total publication of Myanmar. Similar notable growth has been experienced by the

Philippines in 2016 calculated at 33.09%; this has made the Philippines the second highest producer with collaborative countries after Myanmar. On the other hand, China as the largest producer for academic papers has the lowest average number of collaborating countries, even though it shows a positive trend during the period. Similarly, Singapore where international co-authored papers contributed up to 60% to the total publication has less than an average of two collaborating countries for every co-authored paper. Meanwhile, with a declining contribution of international co-authored papers every year, the number of collaborating countries for co-authored papers with Indonesia scholars was raised to two countries in the rest of the period (2006).

Another structure of publication can be seen through the research subject. The subjects of research generally can be classified into four main clusters (social sciences, health sciences, physical sciences, and life sciences) which are constructed from 27 major subject areas. The structure of ASEAN publications has been dominated by physical sciences (60.31%) and followed by life sciences (15.44%). It is similar to the global structure where physical sciences are the major publications, and supported by life sciences and health sciences. Meanwhile, China has a slightly different structure compare to Asia Pacific and total world publications. Physical sciences are the primary subjects in the structure of China publications documented as 74.16%. This subject is mostly supported by engineering (27.3%) and followed by material science, physics and astronomy and computer science. A greater share of publications from this subject has made China the major contributor to science and technology. On the other hand, research in social science has not been popular as physical and life science accounted for a less than 5% contribution. This may correlate with China's national goals to be a global leader in industry, trade and technology.



Sourced: (SciVal, 2018a)

Figure 4. 4 Structure of publications by research subject

4.3 The Structure of Collaborative Research Network

This section will discuss the structure of the collaborative research network. The typology of the collaborative research network is analysed using an undirected adjacency matrix. The total number of international collaborations generally is greater than the total number of international co-authored papers, because one paper can be authored by several scholars from different countries. For example, one paper is authored by ten scholars consisting of three scholars from country O (origin), three scholars from country P_1 (partner 1) and four scholars from country P_2 (partner 2). Therefore, it will be recorded as one international co-authored paper with two international collaborations. Another situation is one paper authored by five different scholars from four different countries which means one scholar for every country, both the origin and partner countries, then it will be documented as one co-authored paper with four international collaborations. In total, the first and second situations can be calculated as two co-authored papers, with 15 scholars and six international collaborations, although

between co-authored paper one and two there are potential similar country partners for different papers or the same authors for different papers. The number of collaborative countries is counted based on every co-authored paper. Furthermore, a co-authored paper does not contain a flow like other matrix data such as flight, migration, trade or investment which widely use directed matrix. Weighted Degree Centrality (WDC) has been selected to analyse the structure of the collaborative research network because the degree of centrality does not count the number of papers (publications) as the weight of each link. In addressing this issue, it is suggested the WDC of country should be used. Every cell of the matrix contains the total number of co-authored papers between two countries, country *i* and country *j,* as a pair collaboration.

Natural WDC is measured by summing up the total weights of links between the country origin to direction countries (as a pair of collaboration with country origin). Since the country's relative size in the region (ASEAN and China) is diverse and large country (with more populations) lead to higher probability of greater WDC, this study employs a number of researchers to control WDC. The number of researchers was selected since they were directly involved in research activities. A technique from Lengyel et al. (2015) has been adopted to address the possibility of extra WDC value in the large country size in the second WDC:

$$WDC_{(2)} = log\left(\frac{WDC}{\overline{WDC}}\right), \qquad (4.1)$$

Where:

$$\overline{WDC} = \frac{WDC}{r} \qquad (4.2)$$

$\overline{WDC}$ is the ratio between total natural weights (*WDC*) in country origin and *r* number of researchers in country origin the expected number of ties between country i and country j.

$WDC_{(2)}$ can have a negative value or a positive value depending on the ratio of the estimated weight and the WDC ratio researchers (Lengyel *et al.*, 2015).

The WDC of collaborative research between ASEAN and China with 209 non-ASEAN countries generally presents a moderately unstable centralities structure over 11 years (2006-2016). China has had the maximum WDC value and placed China as the principal of the hierarchy without any transition with other countries, although they have an annual growth of WDC smaller (0.23%) than most AMS. China has the highest WDC score due to an enormous number of the researcher (more than six times of total ASEAN) followed by tremendous scholarly outputs and IRC (nearly seven times than ASEAN). This condition indicates China performed well in IRC productivities. Therefore, there is a notable gap in WDC value between the first and the following positions in the extra-region structure.

Singapore (2006-2009) and Malaysia (2010-2016) have settled the second ranking during the research period. Singapore's position continuously decreased after 2010 due to WDC value diminished than the beginning period (annual growth -0.16%). Simultaneously, Malaysia has demonstrated substantial improvement of WDC leading to stepping up from the fifth ranking to the second ranking. Malaysia's performance has been supported by a remarkable annual growth (on average 45%) of IRC. The situation indicates Malaysia has been the most internationalized country among AMS for seven years.

Table 4. 2 WDC Extra-Region ASEAN and China

WDC	YEAR										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Brunei Darussalam	3,031	3,044	3,049	3,054	3,059	3,179	3,338	3,341	3,460	3,508	3,567
	9	*9*	*9*	*10*	*10*	*9*	*9*	*9*	*9*	*9*	*9*
Cambodia	3,423	3,455	3,485	3,515	3,543	3,570	3,597	3,624	3,646	3,673	3,689
	8	8	7	8	8	8	8	8	8	8	8
China	**6,079**	**6,144**	**6,193**	**6,052**	**6,073**	**6,110**	**6,137**	**6,161**	**6,172**	**6,198**	**6,217**
	1	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***	***1***
Indonesia	4,317	4,330	**4,450**	4,342	4,465	4,469	4,509	4,547	4,597	4,643	4,670
	4	*4*	***3***	*5*	*5*	*6*	*6*	*6*	*5*	*5*	*5*
Lao PDR	2,971	3,005	3,037	3,068	3,097	3,126	3,152	3,177	3,202	3,227	3,250
	10	*10*	*10*	*9*	*9*	*10*	*10*	*10*	*10*	*10*	*10*
Malaysia	4,139	4,211	4,275	**4,487**	**4,727**	**4,741**	**4,756**	**4,770**	**4,819**	**4,844**	**4,921**
	5	*5*	*4*	***3***	***2***	***2***	***2***	***2***	***2***	***2***	***2***
Myanmar	2,930	2,959	2,986	3,013	3,038	3,062	3,086	3,109	3,131	3,152	3,172
	11	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*	*11*
Philippines	3,837	3,842	3,861	3,875	3,887	3,905	4,029	4,099	4,116	4,175	4,192
	7	*7*	*6*	*7*	*7*	*7*	*7*	*7*	*7*	*7*	*7*
Singapore	**4,666**	**4,681**	**4,696**	**4,712**	4,615	4,561	4,529	4,552	4,560	4,589	4,590
	2	***2***	***2***	***2***	*4*	*5*	*5*	*5*	*6*	*6*	*6*
Thailand	**4,398**	**4,437**	3,359	4,471	4,501	**4,674**	**4,716**	**4,763**	**4,788**	4,774	**4,867**
	3	***3***	*8*	*4*	*4*	***3***	***3***	***3***	***3***	*4*	***3***
Vietnam	3,987	4,050	4,213	4,329	4,384	4,521	4,654	4,732	4,785	**4,799**	**4,812**
	6	*6*	*5*	*6*	*6*	*5*	*4*	*4*	*4*	***3***	***4***

Source: Author

In contrast, the third hierarchy is more volatile. Four countries have contested this position for 11 years (2006-2016), such as Indonesia, Vietnam, Malaysia, and Thailand. Nevertheless, Thailand has been the most prolonged duration (seven years), settling in the third hierarchy.

However, Vietnam presents a positive WDC development compare to the rest of AMS. The growth of WDC value has been annually 1.91%, and total value progress accounted 0.826 within 11 years. As a result, Vietnam's position climbed from the sixth in 2006 to the fourth in 2016.

Another information can be drawn from inter-regional collaboration about country partners for ASEAN and China collaboration. Using the ranking of WDC score allows the identification of the ten most favourable countries as international research partners for ASEAN plus China. These countries have the highest likelihood to undertake collaborative research with ASEAN and Chinese scholars which implies they are the most prominent countries for global academic knowledge. During the period (2006-2016), there are 11 countries listed as collaborator partners, most of them classified as high-income countries (see Table 4.4) referring to the World Bank countries classification data by 2018. This indicates how ASEAN and China have much greater likelihood of collaborating intensively with developed countries than collaborating with low-income economies and/or middle-income countries. The hierarchy for the top ten countries (the highest number collaboration with ASEAN and China) is generally stable for the countries which are included as prominent collaborators and also for the ranking's arrangement. This reflects that these countries have high productivity for international collaborative research and continuously perform positively over the period (2006-2016).

In the meantime, there is a greater possibility that high-income countries perform better on research and development since research activities demand sufficient funds and sustained investment for the long term. Meanwhile, the outcome from research and development through innovation affects productivities enhancement which results in economy growth and development. Rapid growth of economy and development bring advantages in funding accumulation from various sources that can be utilised for investing in knowledge and research in the future. This can be seen as a cycle of correlation between knowledge and economies and this occurs in the majority of high-income countries.

Several reflections can be drawn from above situation. Most of the high-income countries have been positioning knowledge in a central role in national policy to support the economy and development. Knowledge as a source of innovation has been utilised to raise productivity and produce competitive advantages. Second, knowledge accumulation through flows of knowledge and knowledge creation (by undertaking continuous research and development) are crucial to enlarge the internal capacity which is important for a sustainable economy and development. In other words, producing a greater number of academic publications represents a strong knowledge capacity which is conducive to support development. In addition, a robust internal capacity can be the added value for developed countries: they have greater opportunities to collaborate with global countries which contributively accelerates knowledge flows; and simultaneously, this will result in escalating their knowledge capacity.

As seen from Table 4.4 the United States (US) has dominated in the top hierarchy for all years. The US is leading in global knowledge with the highest research productivity and international collaboration in the world. Their superiority in research and development has attracted other countries to undertake research collaborations with the US. It has emphasised its position as first in the ranking through leading on research and innovation in the most subjects.

Table 4. 3 Top ten collaborative country partners for ASEAN and China

Ranking	Years										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	US	US	US	US	US	US	US	US	US	US	US
2	Hong Kong	Japan	Japan	Japan	Japan	Japan	UK	UK	UK	UK	UK
3	Japan	Hong Kong	Hong Kong	Hong Kong	UK	UK	Japan	Australia	Australia	Australia	Australia
4	UK	UK	UK	UK	Hong Kong	Germany	Australia	Japan	Japan	Japan	Japan
5	Australia	Australia	Australia	Australia	Australia	Australia	Hong Kong	Hong Kong	Hong Kong	Hong Kong	Hong Kong
6	Germany	Germany	Canada	Canada	Germany	Hong Kong	Germany	Germany	Canada	Canada	Canada
7	Canada	Canada	Germany	Germany	Canada	Canada	Canada	Canada	Germany	Germany	Germany
8	France	France	France	France	France	France	France	France	France	France	France
9	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea	South Korea
10	Taiwan	Netherlands	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan	Taiwan

Sourced: author

Close to the first position are the United Kingdom (UK) and Japan, which have shifted ranking interchangeably for the second position over 11 years. It seems that the UK and Japan are equally strong collaborators for ASEAN and China which is shown by their contest for the second position in the hierarchy for a similar duration (five years respectively). Table 4.4 presents the hierarchy of countries from across continents which are prominent collaborative countries for ASEAN plus China.

Further information can be seen from Table 4.4 about geographical factors and possibilities for collaboration. Within seven years (2008-2013 and 2016), half of the collaborator partners (Japan, Hong Kong, Taiwan, Australia, South Korea) are from East Asia and the Pacific where ASEAN and China are located. This implies a possibility about relation between geographical proximity and intensity of the research collaboration between pairs. Geographical proximity helps to accelerate communication, coordination and cooperation since shorter distances have been able to reduce constraints in undertaking collaboration. Geographical proximity offers more advantages in terms of efficiency, such as: time, cost and efforts. In addition, this proximity is potentially supported by other circumstances like country performance on research productivity and quality, international collaboration and global university ranking. In the other words, geographical proximity is not a single factor influencing ASEAN and China to collaborate intensively with country partners in neighbouring regions (East Asia and Pacific). In contrast, collaborative research might be undertaken less frequently between countries with limited research productivity and quality, although they are located closely.

Furthermore, the structure of the collaborative research network for ASEAN and China can be seen through Figure 4.6, which describes the interaction between ASEAN countries plus China

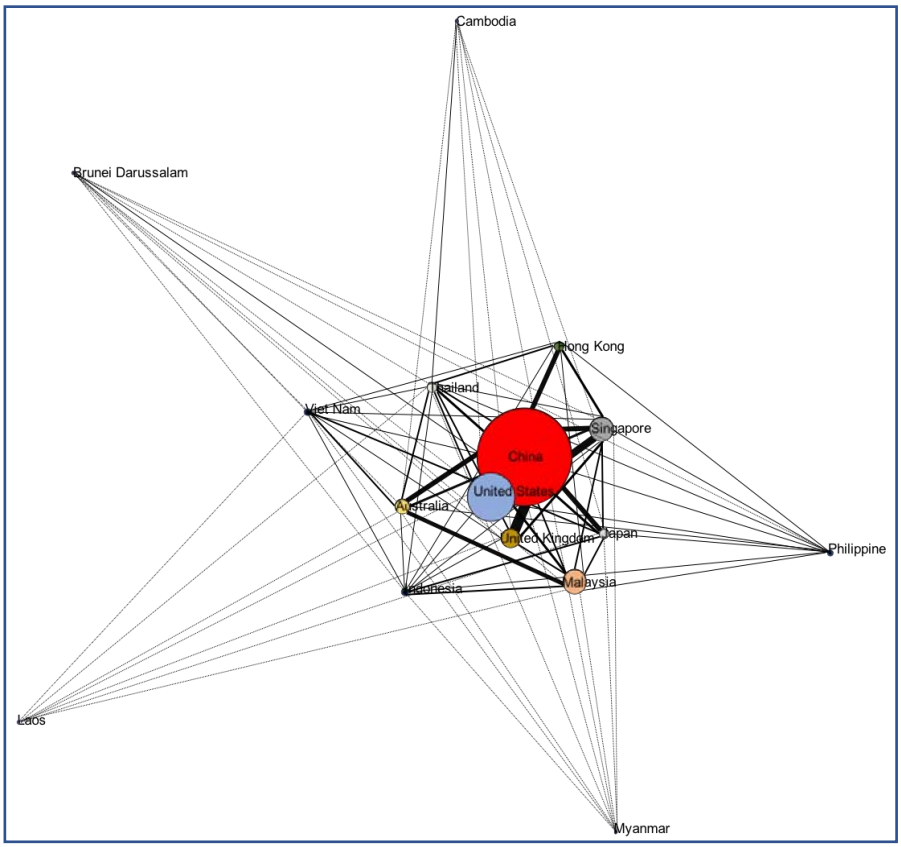
and five prominent collaborative countries such as the US, UK, Australia, Hong Kong, and Japan. The structure of the network has generally formed a star network shape with several countries positioned centrally, in the middle and the rest of the countries dispersed on the peripheries.

China, with the largest node size, is positioned in the core of the network together with prominent collaborative countries, Singapore, Malaysia and Thailand. It appears that the US has been the most favoured external country partner for ASEAN members and China, and also the rest of world. China and the US have the strongest collaboration which is seen through their position in the network as they are shown as closest together compared to the other countries. In addition, China has dominated external collaboration with prominent countries in which collaboration with the UK is the second highest after the US. Besides China, another robust collaboration is shown by Singapore and the US. In the meantime, Singapore also demonstrates vigorous collaboration with China that represents the strongest intra-regional collaboration among ASEAN countries. Another country positioned in the core of the network is Malaysia which has the strongest external collaboration with Australia and Indonesia.

It is interesting that Singapore is located closer to the core while the Malaysian node size is slightly bigger than Singapore. This situation indicates the size of the nodes has not directly determined a closer position to the core in the network. Singapore seems more central than Malaysia in the international collaborative network because Singapore has maintained a greater number of links with country partners as collaborative pairs. It can be said the more central position of Singapore in the network represents Singapore's popularity and potentially gives it a wider influence as many collaborative country partners depend on Singapore. This is supported by evidence that Singapore has been in the highest hierarchy of WDC among

ASEAN countries for a longer period than Malaysia which is reflected in the links between Singapore and country partners being well established.

Moving farther from the centre, there are Indonesia and Vietnam. Vietnam and Indonesia have similar sized nodes but Vietnam's position is more distant from the core than Indonesia. Being located in-between the core and the periphery gives an opportunity for Indonesia and Vietnam to bridge other countries in the periphery to access the core of the network, such as for Brunei, Laos, and Myanmar.



Sourced: author

Figure 4. 5 Network structure collaborative research of ASEAN and China

Moreover, producing a low number of international co-authored papers has impacted the rest of the countries located in the periphery of the collaborative network. This group seem isolated

from each other, particularly when collaboration between them is very low. Access for knowledge flows relies on countries in the core and the middle of the network structure.

The motivation for international collaborative research is primarily to gain new knowledge from external sources. It has naturally encouraged a country to seek the most suitable research partners with a particular capacity which are able to increase internal capacity through something genuine, more advances or even potentially creating new knowledge and generating innovation. Therefore, this presumes collaborating with actors with greater knowledge potentially gives greater knowledge flows that can be utilised to improve internal capacity. Higher capacity is represented through better performance in research and science and manifested in several areas such as: research productivity (number of international publications); impact factor of publication; quality of institution in world university ranking; outcome research and development indicated by innovation and patents; and international academic awards. In the meantime, collaborative research with a low-capacity country cannot be neglected due to this cooperation bringing another opportunity to create new knowledge which can barely be found in collaborative research between high-capacity countries. This implies that some particular new knowledge may only be generated through collaboration with a group of countries with low knowledge capacity since this particular characteristic exists within this group. For instance, innovation in medicine for tropical diseases can result through collaborative research with underdeveloped countries located in tropical countries. Limited knowledge and infrastructure may hamper underdeveloped countries in overcoming tropical diseases by inventing medicine and its mitigation. Meanwhile other countries who are advanced in research in certain subjects related to disease may help to overcome tropical diseases by sharing their knowledge with underdeveloped countries through collaborative research. Even so, collaboration intensity for this type may be not greater and stronger as collaborative research with higher knowledge capacity countries.

4.4 Density of Network

As seen from Table 4.5 it is possible to analyse the interaction of ASEAN and China countries with non-ASEAN countries. Overall, extra-region collaboration has been much greater than intra-region in terms numbers of co-authored papers, although both of them have similar average annual growth (accounted at 17%). The number of co-authored papers between authors from ASEAN/China is only 10% or less than the extra-region collaboration quantity. China on average has contributed nearly half of the total collaborative research for ASEAN per year. Through an individual perspective, China itself has collaborated more externally than internally (with ASEAN) which is reflected by the small ratio of collaborative research within ASEAN compared to collaboration beyond ASEAN countries. As the second largest science producers in the world, China undertakes external collaboration mostly with the US, European countries, the UK, Australia, Canada, Japan, South Korea where innovation and knowledge creation are the most generated. Similarly, ASEAN countries also collaborated more externally, calculated at approximately five times greater than collaboration within with ASEAN members. In the meantime, this collaboration has been continuously growing in recent years. The growth of ASEAN external collaboration shows higher in the rest of the period (21% between 2010 and 2016) compared to the beginning of the period (12% – 2007). This reflects that ASEAN and China have sourced their academic knowledge more externally than internally. External collaboration seems promising for ASEAN and China in terms of knowledge flow and research supports.

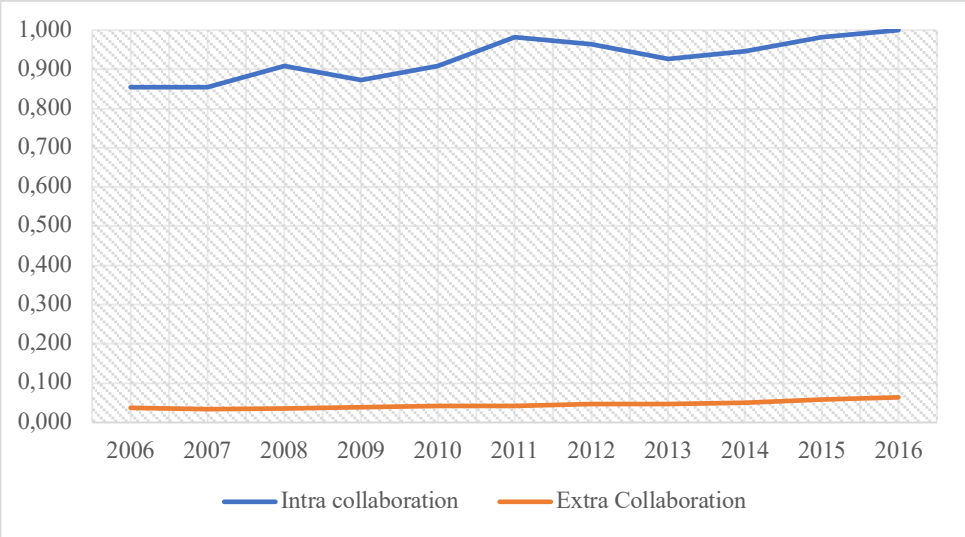
Table 4. 4 Co-authored papers intra-region and extra-region collaborations

Year	Intra-region collaboration			Extra-region collaboration		
	China	ASEAN	ASEAN+ China	China	ASEAN	ASEAN+ China
2006	1,596	3,094	4,690	35,005	14,630	49,635
2007	1,839	3,577	5,416	40,537	16,316	56,853
2008	2,049	4,103	6,152	48,022	19,208	67,230
2009	2,339	4,693	7,032	55,164	21,638	76,802
2010	2,917	5,983	8,900	65,070	26,208	91,278
2011	3,188	6,671	9,859	78,771	31,095	109,866
2012	3,830	8,278	12,108	91,554	38,598	130,152
2013	4,547	9,364	13,911	103,675	44,604	148,279
2014	5,473	10,791	16,264	120,424	55,497	175,921
2015	6,235	12,501	18,736	133,811	66,979	200,790
2016	7,132	15,293	22,425	151,963	81,371	233,334

Source: SciVal, 2017

On the other hand, relations among ASEAN members are founded in formal cooperation within the Southeast Asia region. Meanwhile, cooperation between ASEAN and China was institutionally developed and signed in 2006 through the ASEAN plus China framework. This cooperation is not only limited in the main subjects of cooperation (such as economy, geopolitics, and regional security) but also universities and research activities. Furthermore, it has been expected that the presence of an intergovernmental organisation at regional level conceptually can interlink between countries to get closer and accelerating cooperation between them. Institutional agreements should help to minimise communication barriers like legal frameworks and streamline common goals among members. All these efforts ideally can strengthen cooperation and embody results in rigorous collaboration. Unfortunately, this expectation cannot be seen clearly from intra-regional collaboration, either among ASEAN members or ASEAN and China. This point may reflect that formal engagement does not guarantee cooperation is always more solid, particularly for collaborative research between countries.

Density can be defined as the number of existing ties divided by the potential (maximum) number of links in the full network with the same number of nodes (Otte and Rousseau, 2002). In addition, density can be used to analyse interaction between countries (Cheliotis, 2010). The index of density is in the range between 0 and 1.0; where the value of density is close to 1.0 the network tends to be dense, alternatively the network is scattered. A denser network reflects the closer relation between countries in the network and vice versa. A full connected network has a value of 1.0 which is called as a clique (Cheliotis, 2010). It needs to be considered that density is sensitive to the total number of network nodes.



Sourced: author

Figure 4. 6 Density of extra-region collaboration (2006-2016)

Since there is a limitation in obtaining data for global collaborative networks with 220 countries as the pairs lead to an incomplete network of extra-regional collaboration, extra-regional collaboration could only generate collaboration between ASEAN countries plus China (11 countries) pairing with 209 countries. An incomplete network may affect the small value of

density (as seen in Figure 4.7). Density for extra-regional collaboration generally demonstrates improvement over the period, although certain years experienced negative growth (Figure 4.7). For example, density declined -10.61% (2007) for extra-regional collaboration.

The number of co-authored papers varies across years as research collaboration is not constant. The activities on collaborative research are mostly determined by the individual's (researcher's) interest which is leading to more dynamic change if this should be aggregated in rows of years. This situation may happen for countries with low capacity in academic and research performances, such as from underdeveloped countries or low-income economies, not constantly collaborating with ASEAN and China every year. There were several periods when these countries rarely existed in the collaborative network. In contrast, countries with a high capacity in academic knowledge and research performance are the most vigorous collaborator partners for ASEAN and China shown through higher WDC ranking. This group of countries have the likelihood of strong connectivity with ASEAN and China, meanwhile the group of countries with few collaborative research activities may have weak interconnectivity. The widening gap between groups with high intensity and low intensity of collaborative research has led to a small value of density, particularly when the group of top ten collaborator partners have dominated nearly 70% of total co-authored publications. Meanwhile, 199 countries share only approximately 30% of the total collaboration.

There are two implications from density value. Low density implies poor connectivity between collaborator partners as demonstrated by extra-region collaboration. A low density usually occurs in wider networks which involved greater numbers of actors. It has impacted on flows of knowledge that may not be as smooth and greater intensity than in denser networks leading

to lower possibility to acquire advantages from the collaboration. Therefore, collaborative research as flow of knowledge may have a little contribution on generating innovation.

The stability of density over 11 years indicates that there is not much realisation from potential connections to the actual connections due network density concept is actual connections divided by potential connections. ASEAN countries and China tend to utilise existing connections instead of bringing the potential collaborations into real collaborations. Since collaborative research is a complex process, building a real collaboration requires strong efforts such as frequent communication, reciprocal social-physical interaction, the flexible means of coordination methods, and some efforts from both sides research partners to develop trust and mutual collaborations (Jentsch and Pilley, 2003; Mêgnigbêto, 2013; Huggins and Thompson, 2014)

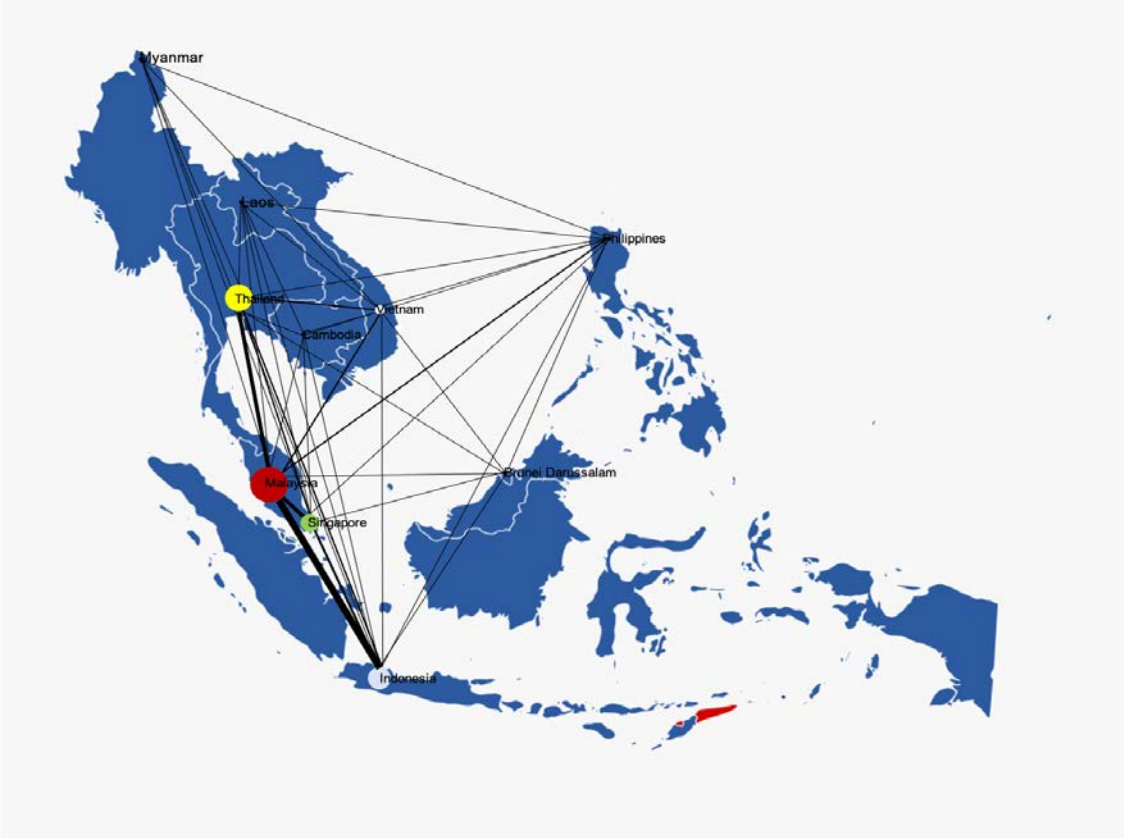
Existing connections generally have more robust collaboration than newer connections leading to path dependency. Universities or research centre naturally following prior collaboration path that mostly has remarkable academic research reputation and research specialization (as the main prerequisite of collaborations) (Meyer, 2007; Han and Yim, 2018). In the meantime, a diverse academic research performance between countries impacted on unequal opportunity to be selected as the most favorable research partners.

Besides, density stability brings further impact on community structure ((Rinaldo *et al.*, 2012). The community structure will not change so much because there are no notable additional connections from the potential connection. In other words, the community members of collaboration between ASEAN and China with the rest of the world countries tend to be steady

over the period due to fewer new actual connections were built; thus, an intense collaboration will dominate existing connections.

4.5 Community Detection

Investigating the intensity of intra-ASEAN research collaboration is pivotal to identify how the interaction has developed between members within the region. A map of collaboration frequency has presumed reflecting how AMS are undertaking collaborative research with non-ASEAN countries and established the communities. Intra-ASEAN collaborative research presents a different network structure compare to extra-region collaboration. Intra-ASEAN collaboration seems less dynamic than the collaboration between AMS and non-ASEAN countries. A vast disparity number of IRC occurs among AMS. The members tend to engage with non-ASEAN countries because the ASEAN Secretariat plays the least influential role in governing AMS and enforcing cooperation between AMS (Frost, 1990; Ito, 2013; HA *et al.*, 2016). Besides, an absence of a formal coordinating board to promote academic collaboration indicating intra-ASEAN collaboration has not been one of the ASEAN Secretariat's developments priorities. This situation has been worsening due to the limited roles of AUN and the lack of incentives within the region to promote intra-ASEAN collaboration (Rezasyah *et al.*, 2017; AUN, 2020).



Source: Author

Figure 4. 7 The Intensity of Intra-ASEAN collaborative research

Malaysia, Thailand, Indonesia, and Singapore are the four most prominent nodes among 10 AMS during the period (2006-2016). As the most excellent intra collaboration country, Malaysia has strong ties with Indonesia, Thailand, and Singapore. Malaysia-Indonesia is the most vigorous cooperation in the region, contributing nearly 20% to total intra-region collaboration. Malaysia and Indonesia are geographically neighboring countries with a similar culture and spoken language, Melayu. Also, Malaysia and Indonesia have a long history in academic cooperation before the 1980s when Indonesia sent numerous teachers and lecturers to assist education development in Malaysia (Wilson, 1991). In the meantime, Malaysia, Singapore, and Indonesia have strong economic cooperation such as trade, industry, and investment that regionally called triangle economy (Ooi, 1995). This situation has presumed to

influence intense collaborative research between Indonesia and Singapore, and Singapore and Malaysia. Similarly, Malaysia and Thailand have connected by cooperation in the manufacturing and agriculture sectors (Reinhardt, 2000; Wad, 2009), stimulating more frequent research collaboration within these research subjects.

In contrast, Myanmar, Laos, Cambodia, and Brunei Darussalam are the smallest nodes within an intra-region collaboration. The number of collaborations over 11 years (2006-2016) has grown so little due to insufficient condition for research environment, like inadequate research budget, domestic issues (such as conflicts of politic and security), and low performance in education and research (Battersby, 1998; Cuyvers, 2019). The weak ties are found between the smallest nodes and the four most prominent nodes. Interestingly, Thailand has been a central collaborator for Cambodia, Myanmar, Laos, and Vietnam (CMLV). Geographical factor, represented through water diplomacy, has formed a robust relationship in politics and economy between Thailand and CMLV, named "Mekong Basin" (Battersby, 1998; Dosch and Hensengerth, 2005; Kittikhoun and Staubli, 2018). Geographical factor and economy relation have been presumed to influence the research collaboration of CMLV with Thailand than the other prominent AMS. Therefore, the collaboration intensity between countries indirectly has formed certain groups within the region related to spatial and economic cooperation.

A community is determined as a group of actors that interact closely and reciprocally compared to other actors within the network. It is generally constructed by individuals inside a group and who have communication more often within members in the network compared with other members beyond the group (Bedi and Sharma, 2016a). Identifying a community can be done via graph partitioning and clustering. Partitioning is the process used to define a number of smaller elements with particular features, generally using heuristics. A general element to be

minimised is namely cut size. Detecting a community using this method requires information of the number of communities. Since there is no such prior information, graph partitioning approaches are not fit to identify communities in this study. Meanwhile, clustering can be seen as process to create a group based on a set of similarity characters in the structure. Clustering gives various information about unseen fundamental features, interaction, and elements from interactions between actors. In addition, clustering also helps to see how actors connect and communicate with each other because of similarities of character, proximity and interest. Creating a hierarchical cluster can be done by agglomerative and divisive methods. Certain nodes are clubbed or aggregated with other similar nodes to form a community which is based on a bottom-up approach and closeness. On the other hand, a divisive clustering method is dividing a large group into smaller communities. Nonetheless, the use of algorithms for community detection widely uses the clustering approach (Bedi and Sharma, 2016a). The characteristics of a fast greedy community has been used to identify a community, since it is one of the hierarchical approaches and widely used in quantitative analysis (Orman, Labatut and Cherifi, 2012).

A community detection of extra-region collaboration has employed a fast greedy community in RStudio. The algorithm has resulted in two outputs: a table consists of list members for every community and a community network graph. Unfortunately, since external collaborative research is an incomplete network, the community graph is dominated by nodes of a single country, affecting the community structure has not been clearly visible to identify. Therefore, a table of community list is selected to detect the community. A community defines a minimum of two countries within a group due to collaborative research requiring at least two countries as collaborators as a full connection.

The communities for extra-region collaboration have brought three communities which have full connections between members. The rest of the communities (approximately 48) are loose communities in which only one country belongs to each community. This means a country within a community has no interaction with another country. Most of these communities are occupied by low-income countries. This situation may be caused by an incomplete network of extra-regional collaboration where 209 countries have not paired reciprocally leading to an incomplete community graph. Nonetheless, community detection is crucial to identify similarities and relations between ASEAN and China with rest of the world countries. Analysis is focused on three communities where interaction between members exists (see Table 4.8) and limited to 11 countries as the total number of top ten collaborators during 11 years for ASEAN plus China. This is considered with consistency to another finding in the previous section about the most favourable countries for ASEAN and China research partnerships.

Table 4.8 shows how communities of extra-region collaboration have exchanged reciprocally over the periods both for hierarchy and with members of the community. For example, at the beginning (2006) there were three communities and ASEAN members were grouped in the first and the third communities, while China stood in second group together with the United Kingdom, United States, Japan, Canada, Germany and Hong Kong. Later, the number of communities have lessened to two groups for eight years (2007-2011 and 2014-2016), though in the middle periods (2012-2013) three communities exist in which ASEAN members are scattered in two different groups. For instance, in 2012 when Brunei Darussalam, Malaysia and Singapore were grouped independently from other ASEAN countries; and, in 2013 when Indonesia joined the third communities like in 2012. Nevertheless, ASEAN countries seem gathered in a community more often than sparsely scattered in different communities. In the

meantime, the third community during the period of 2007-2011 and 2014-2016 has been solely occupied by non-prominent collaborative countries, which means a country with a low number of collaborations with ASEAN plus China, such as American Samoa, Afghanistan, Angola, Antigua and Barbuda, Anguilla.

Table 4. 5 Community structure of extra-region collaboration

Year	Community 1	Community 2	Community 3
2006	*Brunei D, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand,* Australia, Netherlands, Taiwan	*China,* UK, US, Japan, Canada, Germany, Hong Kong	*Cambodia, Vietnam,* France, South Korea
2007	*China,* US, UK, Japan, Canada, Germany, Hong Kong, South Korea, Taiwan	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* Australia, France, Netherlands	*Non-Prominent Collaborator* (American Samoa)
2008	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* UK, Netherlands, Australia, France	*China,* US, Japan, Canada, Germany, Hong Kong, South Korea, Taiwan	*Non-Prominent Collaborator* (Angola)
2009	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* UK, Netherlands, Australia, France	*China,* US, Japan, Canada, Germany, Hong Kong, South Korea, Taiwan	*Non-Prominent Collaborator* (Afghanistan)
2010	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* UK, US, Netherlands, Australia, France	*China,* US, Japan, Canada, Germany, Hong Kong, South Korea, Taiwan	*Non-Prominent Collaborator* (American Samoa)
2011	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* UK, Netherlands, Australia, France	*China,* US, Japan, Canada, Germany, Hong Kong, South Korea, Taiwan	*Non-Prominent Collaborator* (Angola)
2012	*China,* UK, US, Canada, Germany, Hong Kong, France, Taiwan	*Cambodia, Indonesia, Laos, Myanmar, Philippines, Thailand, Vietnam,* Netherlands, Japan, South Korea	*Brunei D, Malaysia, Singapore,* Australia
2013	*China,* UK, US, Japan, Canada, Germany, Hong Kong, Taiwan,	*Cambodia, Laos, Myanmar, Philippines, Thailand, Vietnam,* France, South Korea	*Brunei D, Indonesia, Malaysia, Singapore,* Australia, Netherlands
2014	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* Netherlands, Japan, Australia, France, South Korea,	*China,* US, UK, Australia, Canada, Germany, Hong Kong, Taiwan	*Non-Prominent Collaborator* (Antigua and Barbuda)
2015	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* Netherlands, Japan, France, South Korea,	*China,* UK, US, Canada, Australia, Germany, Hong Kong, Taiwan	*Non-Prominent Collaborator* (Anguilla)
2016	*Brunei D, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam,* Netherlands, France, South Korea	*China,* UK, US, Canada, Australia, Japan, Germany, Hong Kong, Taiwan	*Non-Prominent Collaborator* (Anguilla)

Source: author

On the other hand, China is located apart from the community of ASEAN countries during the 11 years under study. China for most of the time has stayed with prominent countries like the

United States, United Kingdom, Canada, Germany, Hong Kong and Japan in the same community. These countries have been recognised as countries with the highest number of academic publications and international co-authored papers. None of the ASEAN countries has been located within one community with China because of the wide gap in academic output between China and ASEAN countries. China's total academic output is more than seven times greater (annually) than the total academic output of ASEAN countries. Furthermore, by the total number of international co-authored papers, China has an output of two and a half times more than the total from ASEAN countries. Among ASEAN countries, only Singapore has a greater ratio than China for international co-authored papers (15% annually). Nevertheless, Singapore's ratio seems smaller than the other prominent countries which have a ratio of more than 30% per year.

The detection of a community for extra-region collaboration implies important findings. *First*, the size of the academic capacity is a measure used to group countries within the same community. China together with prominent producers of academic knowledge like the United States, Japan, Germany and Canada are grouped into one community leaving ASEAN countries in a separate community.

Second, historical factors which are manifested via colonial relations that are recognised as existing between countries. As seen from Table 4.8, colonialism is apparently visible over community relations, for instance between Indonesia and the Netherlands which have always belonged to one group during 11 years. There was a period (2013) when Indonesia separated from major ASEAN members but the Netherlands and Indonesia remain situated within a community. Another clue shows through the relation of Singapore, Malaysia and Brunei Darussalam with the United Kingdom which have been together as a community for at least

five years. Relations between the United Kingdom and its colonies are perhaps not as strong as between the Netherlands with Indonesia, but despite this it gives a signal of the colonialism that affects international collaborative research.

Third, similarity of sociocultural factors contributes to international collaborative research. China, Hong Kong and Taiwan have spent most of the periods within the same community. In addition, Taiwan's and Hong Kong's ancestors are rooted in mainland China and have brought impacts on language and culture between them. Language and cultural closeness can support communication and accelerate interaction between two and/or more different entities, since wider disparities in language and culture can be a barrier in undertaking international collaboration. The less contrary factors against cooperation leads to a greater possibility for collaboration.

Fourth, geographical proximity and community. As discussed in the previous section geographical proximity is crucial in determining the propensity to collaborate, as geographical factors provide another effect on the formation of a community. A shorter distance between countries reduces the barriers to build closer interaction by having more intensive communication and probability of holding meetings more often. As a result, the higher intensity of cooperation between actors can form a community in which actors depend on each other. This can be seen both within ASEAN and with non-ASEAN countries that are grouped in the same community. The members in these groups are directly connected as neighbouring countries, for instance the group of four (Indonesia-Malaysia-Singapore-Brunei Darussalam); Cambodia-Vietnam; Indonesia-Australia; and the triangle of Chinese countries (China-Hong Kong-Taiwan).

Fifth, similarity in academic performance and likelihood of residing within a community. Academic performance represented by the quality of the research, a world class institution, and international publications have been recognised as the push and pull factors to undertake international collaboration. Similarity in performance of academic knowledge is conducive to bringing a closer relationship between countries. This has been reflected via greater numbers of research collaborations as a proxy of the suitability and convenience arising from the cooperation. This is one of the indications shown by China and United States when paired as community members along with other countries for 11 years. The United States has been widely known as the highest producer in global academic knowledge, while China is currently known as the second biggest in international academic knowledge after the United States. The similarity of academic capacity between them has influenced the development of their community membership.

4.6 Concluding Discussion

The general structure of international collaboration has not much changed in the last decade. China and several country members of ASEAN, representing GS countries, remain dependent on GN countries for academic knowledge flows. ASEAN and China produce ten times the number of co-authored papers with non-ASEAN countries than within regional collaboration. The weighted degree centrality (WDC) for extra-region collaboration is calculated greater than intra-regio collaboration. This reflects that most of the external knowledge has been sourced internationally than regionally. External sources seem promising for GS countries to carry out collaborative research, particularly with outstanding performances in education and academic knowledge, research quality, international publication and institution capacity. In addition,

countries which have been leading in academic knowledge will be a centre of global knowledge where the rest of the world refer to them.

The findings from this study are relevant to the previous study about GS countries' dependency on GN countries in terms of North intervention to South through colonialism (Moore, 2017), economy and trade (Rigg, 2016), and the limitation of resources and instability faced by GS countries (Pagel *et al.*, 2014). Insufficient internal knowledge capacity between GS countries has been the main driver to seek external knowledge that is particularly abundant in GN countries (Fischer, 2001; Popadiuk and Choo, 2006; Ponomariov and Toivanen, 2014b; Cruz-Gonzalez, Lopez-Saez and Navas-Lopez, 2015). However, it is challenging to bring mutual collaboration for both sides while the dependency relation is unequal.

In the meantime, international collaborative research has spread widely by involving a greater number of countries. It can be seen from both intra-region and extra-region collaboration where the network density score has grown positively. Network density has been getting denser by the year, which indicates countries are more connected through co-authored publications. The denser network has brought stronger cohesion, reflecting a dependency between members of intra-regional collaboration. Higher cohesion between members is conducive for knowledge flows between country members within a region. Cohesion helps to reduce barriers, cost and time to transfer knowledge, filtering information and resulting in accurate information (Fritsch and Kauffeld-Monz, 2010). Overall, knowledge flows among ASEAN countries plus China have been more fluent and strengthen cooperation between members. Although collaboration between GS countries has not been as great as collaboration between GS countries and GN countries, the attention to international collaboration continuously expands as well as awareness of the importance of collaborative research activities among GS countries. This can

be seen by several ASEAN members promoting international co-authored publications as fundamental contributions to their academic outputs.

Furthermore, international co-authored publications are related to the structure of publications. Countries with limited performance in academic publications, such as Cambodia, Laos, Myanmar, Vietnam, tend to have a greater share of international co-authored papers accounting for more than half of their total publications which have continuously increased during the period. This shows that international co-authored papers have been a fundamental source for their publications since they have limited internal academic resources, (e.g. Singapore). It is supported with the evidence of limited contributions of national co-authored publications which indicates low collaboration between institutions within the nation and high dependency on international sources for knowledge flow, while a country with a greater academic performance and/or a wider geographical area is likely to have greater internal collaboration instead of international collaboration, such as China and Indonesia.

There are various factors contributing to the continued low performance in international collaborative research for the rest of countries in ASEAN:

1) Collaborative research demands English as an international language in communication and publishing a paper. Many ASEAN countries encounter the use of English as an international language as a disadvantage because the majority of national journals are written in the home language of the country of publication. This may rarely happen for Singapore, Philippines and Malaysia where English is widely spoken in daily life. In the meantime, most of the journals in the ASEAN countries still have low impact factors due to their being written in the local language that may solve problems in local areas

than can be used for global researchers. This situation creates a distance between scholars within ASEAN with global communities.

2) Diverse stages of infrastructure development in information and communication technology (ICT) between ASEAN members has impacted in limited information flows and hampers communication within ASEAN and global researchers (Gholizadeh *et al.*, 2014). This affects responses from ASEAN scholars to global dynamics will potentially be delayed, especially for the current issues which require prompt solutions through innovation.
3) Limited research funding and research quality. Most of the ASEAN members are categorised as low-middle-income countries (with the exception of Singapore which is included as a high-income economy). This has brought risks that research entities are underfunded leading to poor research quality. Since education and research activities have not put as the main agenda in national development plans, the quality of these sectors has developed slowly due to insufficient budget allocation for these areas. Encountering budget limitations on research encourages research institutions to seek alternative funding to finance their activities; one of the methods is through collaborative research with developed countries (Freshwater, Sherwood and Drury, 2006; Jeffery, 2013; Li, Liao and Yen, 2013; Chetwood, Ladep and Taylor-Robinson, 2015)). In contrast, in the other parts of the world, the economic performance is linear to research and education performance (Vayrynen, 1998; Chua, 2001; Rusly, Yih-Tong Sun and L. Corner, 2014).
4) Low performance of education institutions and lack of human resource capacity. In the meantime, among ASEAN members only a few countries have universities which are recognised globally as world best universities, while the rest of the countries are far from the top 500 best universities in the world. Lack of research quality in universities

will affect teaching methods and knowledge capacity in academic areas which are broadly used to calculate university performance. In addition, there is a substantial demand to increase the ratio of researchers with PhD qualifications to the total population in most of the ASEAN countries since the number of scholars with PhDs is low compared to developed countries. PhD graduates are principal in academic and research areas because PhDs have been exercised and examined in a comprehensive process to create new knowledge during the PhD journey. The greater numbers of scholars with a PhD qualification will impact on a higher research performance.

5) Research type and unbalanced performances among research subjects have impacted on low institutional valuation of world ranking. Research undertaken by ASEAN scholars generally forms a pattern of narrowing into a certain focus to meet international standards in particular research subjects, for example bioscience and medicine for tropical diseases and agriculture (Sombatsompop *et al.*, 2011). This has created unbalanced performances in the other subjects which are not included in the primary targets of national research plans for the members from ASEAN. Meanwhile global university ranks are measured by wider regular research subjects, such as social sciences, health sciences, life sciences and physical sciences. Unfortunately, their efforts in publications have not given significant results because of incompatibility between unbalanced performances at micro areas but measured at macro level.

The structure of the collaborative network generally has formed by three different groups based on their position: centre, middle and periphery. Countries located in the core of network, like China, Singapore and Malaysia, possibly generate greater advantages than the other countries which are located farther from the centre (Ter Wal and Boschma, 2009). Through their position in the centre of network, they will acquire greater knowledge flows from their roles by bridging

between countries in the periphery. For example, studies about a specific subject in agriculture was previously undertaken between Thailand and China because Thailand is the highest producer in the agriculture sector in ASEAN. Moreover, China reformulates the findings by conducting further research that results in innovation in agriculture. In the meantime, other low-income countries like Cambodia and Myanmar intend to study further about similar subjects which has been promoted by China with particular innovation in the agriculture sector and will propose collaborative research with China. In this case, China will obtain two side advantages: knowledge from its collaboration with Thailand and another collaboration with Cambodia and Myanmar. Furthermore, this situation has enlarged the dependency of lower-capacity countries which are located in the periphery to China as the core of the collaborative research network. Higher dependency on the core will raise an opportunity for the countries in the core intervening in the network. In reality, intervention can be possibly manifested through an association for a specific research subject in which the association is dominated by countries in the core. From this point, intervention is not limited only via research and publication activities but can be applied in wider sectors such as trade, investment and the other cooperation between countries in the region. Another benefit for countries which are located in the centre of the network is widening opportunities to build new collaborations with other countries. Countries in the core usually have consistently excellent reputation in producing academic knowledge. This reputation will attract other countries to learn and obtain knowledge flows by undertaking collaborative research with countries in the core of network. Therefore, utilising several advantages from their position in the core of the collaborative research network will be conducive to increasing their performance in academic knowledge and enlarging their internal capacity.

There are various factors determining the performance of China, Singapore and Malaysia which are located in the core of the network. The growth of China's academic publications has been remarkable since 1990 and placed China as the second most productive in publishing papers in the world after the US (Jufang and Huiyun, 2011; Xie, Zhang and Lai, 2014). Interestingly, most of the papers were written in English and published outside of China, like in the US and the UK. This reflects how China has been accepted worldwide as a collaborator partner. Several strategies have been undertaken by China to accelerate academic publications, ranging from providing particular incentives to calling Chinese diaspora back to China (Xie, Zhang and Lai, 2014). At an early stage (1895-1949), the Chinese government built Western-style universities and followed the Japanese influence to improve quality in the higher education system across China (Chen, Liu, and Ma 2017). After institutional development as the foundation for the education system, it has continued with giving rewards as incentives for scholars and institutions. This strategy is believed as the best method to stimulate both scholars and institutions in increasing academic productivity. Scholars publishing in a high-rank journal will receive money, either directly to the scholars or distributed via funding support for institutional development. Furthermore, scholars have an opportunity for career promotion in several academic organisations since their research has been acknowledged internationally. In the meantime, the institution also receives another advantage in improvement of its reputation which leads to increasing fees for students and investment from the private sector through joint or collaborative research. Collaborative research is also promoted nationally, particularly after the Chinese government adopted the European Union (EU) strategy on an interregional collaborative research agency called the European Research Area (ERA) (Bayoumi, Coe and Helpman, 1999; Hoekman, Frenken and Tijssen, 2010c). ERA has been translated into a particular board with the main objectives of promoting collaborative research between provinces in mainland China and providing adequate funds to support collaboration

(Wanzenböck, Scherngell and Lata, 2015; Scherngell and Hu, 2017). In addition, China has employed Universities and public Research Institutes (URIs) and the Chinese National Innovation System (NIS) as the main agenda in national development plan to foster research activities, publications and collaboration between provinces (Chen and Kenney 2007). Another goal from this policy is reducing the gap performance on education and knowledge performance between provinces which is expected to promote income distribution as well. This is supported by launching The Grand Western Development Programme to accelerate collaborative research activities. Lastly, the government has called in Chinese scholars who live internationally as diaspora around the world to return to mainland China. It has been done by providing positions at diverse institutions, like research centres, government offices and universities.

As the smallest country (721.5 km^2) in ASEAN, Singapore has been leading in collaborative research within the region and in international publications. Magnificent academic performance fundamentally is supported by institutions, language, and size of countries. Several world class universities exist in Singapore such as the National University of Singapore (NUS) and Nanyang Technological University (NTU) recognised as in the top 100 in the world and Asia. English is the first language which is widely spoken by Singaporeans. Having sufficient capacity in English is conducive to opening broader opportunities to collaborate with global scholars and provides a greater likelihood of publishing academic papers in international journals. In the meantime, the size of countries does not hamper international collaboration. A small country has a greater likelihood of collaborating internationally than nationally because of limited internal sources and capacity to do collaborative research. In contrast, large countries such as the United States tend to collaborate internally since they have extensive academic sources (Vieira and Gomes, 2009).

Moreover, Malaysia has shown significant improvement in international research collaboration for more than a decade and risen to the top group in the hierarchy. Included in one of the wealthy countries in ASEAN, the government, through the Ministry of Higher Education, has expanded budget allocation for research in universities (Kumar and Jan, 2013; Kumar, Rohani and Ratnavelu, 2014) with the expectation it will provide sufficient funds to support research activities. Another programme launched by the government is 'knowledge for development' (K4D) which has been properly translated into the sub-national level by developing knowledge clusters in Peninsular Malaysia, particularly the North Corridor-Penang Knowledge Cluster and the Multimedia Super Corridor–Cyberjaya Knowledge Cluster (Purwaningrum *et al.*, 2014). Meanwhile, at the macro level, Malaysia is following a national programme for a knowledge-based economy (KBE) to accelerate economic development which aims to produce the strongest economy in ASEAN by 2020 (Kumar, Rohani and Ratnavelu, 2014). These strategies show how Malaysia has established national development based on knowledge and provides space for research activities to grow.

The experiences of China, Singapore and Malaysia to accelerate their performance in academic knowledge represents sufficient absorptive capacity. Absorptive capacity is central in determining position in the network (Ter Wal and Boschma, 2009). Absorptive capacity helps in acquiring external knowledge and transforms and accumulates into internal capacity. This is continued by generating internal knowledge to create further knowledge through research and development. Since every country has a different absorptive capacity not all countries can have similar opportunities to be located in the core of network.

In contrast, countries located in the periphery of the network have a low performance in collaboration. This can be seen by Laos, Myanmar and Cambodia having little collaborative research work due to the limited number of international publications. Domestic factors such as low-income economies and instability of politics and security will result in poor performance in academic areas. This finding is relevant to prior study on ASEAN international collaboration in the economics subject area conducted by Kumar et al (2014) which found a similar result. Meanwhile, Brunei Darussalam with high-income economies and stability in domestic situations still has poor performance in collaborative research. As a rich oil producer, Brunei Darussalam demonstrates a different situation compared to the other three low-income countries. The growth of overall subjects in academic publications is relatively low due to narrowing research publications mostly on oil and gas in regard to their economic background. This situation has been experienced by major ASEAN countries. Formal agency or boards at national level who promote collaboration do not exist which impacted on collaborative research, which has not been so popular.

From the structure of collaboration, it is possible to distinguish a general trend between income economies and likelihood of collaborating internationally. Countries with high performance in economy tend to have greater collaborative research activities and also greater numbers of international publications. This can be seen from Singapore and Malaysia. Moreover, China currently as the most populated country (1.386 billion) with the second highest world GDP (12237.70 billion US dollars) has the second highest world international publications after the United States. The remarkable growth of the Chinese economy several years ago has correlated with a growth in knowledge and research activities, although China is included in the low-middle economy group. On the other hand, Cambodia, Myanmar and Laos are categorised as low-income economies and have low academic performance both for international publications

and collaborative research. Therefore, these two different pictures demonstrate that economic performance is fundamentally required to support research activities, particularly through sufficient funding. Lack of funds will contradict with the spirit to promote research as part of the foundation for the economy and development framework. Furthermore, domestic factors such as political and security stabilities are strongly required to generate a favourable environment to grow research and innovation, and also provide a promising atmosphere for international cooperation with a wider range of potential collaborative partners.

International collaborative Research in ASEAN and China bring some reflections. *First*, the presence of an intergovernmental organisation ideally has been critical in promoting international cooperation between members in the region, especially through bridging interests and accelerating communication for solid cooperation between members. This practice is linear with similar experience conducted by EU countries using ERA. Narrowing into the specific purpose of fostering academic cooperation, ASEAN developed the ASEAN University Network (AUN) and ASEAN+3 University Network (ASEAN+3 UNet) with the main objectives of empowering the Southeast Asia research community to be more competitive and enlarging education regionalism across the members in region (Gill, 2018). In fact, the present of AUN may work on promoting people-to-people mobility within ASEAN instead of academic cooperation between universities in ASEAN. This can be seen through a wide disparity of academic publications and IRC among the members.

Second, the size of academic capacity influences the probability of residing within a community. Similar capacity may promote stronger international collaboration between countries and this has impacted on a closer position in network structure reciprocally and staying in the same community.

Third, external factors are indicated as determining the possibility to undertake international collaboration, like country size, spatial closeness, culture and language similarity, and historical relation (colonialism). Academic collaboration is fundamentally motivated by how the cooperation can bring greater satisfaction from the cooperation for collaborators on both sides (Olson, Zimmerman and Bos, 2008). The pleasure from collaboration is articulated through the "enjoyable and friendly" nature of the partnership in the long period of cooperation (Hayat and Llyons, 2017). It means that individual preference has been the central spirit to build a partnership. Social interactions have facilitated building trust between actors before collaboration started (Broekel and Boschma, 2012); later, it will determine how strong collaboration will be and how long cooperation will be sustained (Agrawal, Kapur and Mchale, 2008). Every actor tries to seek suitability and convenience from the collaborators. At this point, various factors feature in the decision process of who will collaborate with whom. From the experience of GN countries in Southeast Asia, four main determinants have been indicated as influencing ASEAN countries undertaking collaboration. These findings are similar with previous studies which have been conducted mostly in developed countries, for example geographical proximity (Quatraro and Usai, 2016); similarity of history, culture and language (Zitt, Bassecoulard and Okubo, 2000); institutional capacity (Melin and Persson, 1996; Melin, 1999; Schubert and Glanzel, 2006); and the other factors together with spatial proximities such as economic performance and country size (Jarneving, 2010). Furthermore, all of these factors determine the structure of the collaborative research network and will be analysed specifically in the following chapter (5) about determinant factors influencing international collaborative research through co-authored publications.

As a result, international collaborative research has been a central approach for global knowledge flows; many countries have been promoting international co-authored papers to acquire external knowledge. Greater numbers of international co-authored papers published by countries can accelerate global knowledge inflow. Obtaining external knowledge will elevate internal countries' capacity and simultaneously update them with the current conditions. In other words, the numbers of international co-authored papers can be used to identify the degree of an internationalised country. It presumes the more internationalised a country, the more the country will be more responsive to global dynamics. The country may respond to global situations through intensive research and development activities which are manifested in new methods or approaches, knowledge creation, new technology and innovations which are beneficial to overcome domestic challenges and also improve country competitiveness. The analysis of the impact of knowledge flows on performance innovation will be discussed further in chapter 6.

CHAPTER V

DETERMINANT FACTORS INFLUENCING INTERNATIONAL RESEARCH COLLABORATION IN ASEAN AND CHINA: EVIDENCE FROM A PANEL GRAVITY

5.1. Introduction

The efforts in developing IRC obviously manifest in cost and time dimensions. Geographical proximity is fundamental in determining cost and time, such as for travel, building access and communication. This implies geographical proximity as the predominant element influencing the probability of carrying out international collaboration. Numerous studies have investigated the impact of location factors on the probability of undertaking IRC. For instance, a study by Katz (1994) measured the impact of geographical proximity on collaboration between universities in high-income countries like the United Kingdom, Canada and Australia. Several research studies observed the impact of geographical factors on knowledge flows, particularly through co-authored publications as representations of research collaborations (Liang and Zhu, 2002; Ponds, van Oort and Frenken, 2007a; Frenken, Hardeman and Hoekman, 2009). In the meantime, technology and innovation in the communication sector have been growing rapidly. The advances development and innovation in information and technology (IT) have accelerated communication between researchers which is getting faster, more fluent and more efficient. However, face-to-face meetings with regard to collaborative research activities are still fundamental, particularly during the process of engagement, reporting and attending conferences or seminars. As a result, the effect of geographical proximity and agglomeration economies for generating research and innovation activities has been a focus of the conventional paradigm (Storper, 1997; Maskell and Malmberg, 1999).

Geographical proximity has recently been seen as a less important element for researchers to undertake IRC while it generates the non-geographical proximities, such as social-cultural, institutional, organisational and cognitive (Malmberg and Maskell, 2006; Hansen, 2015). These factors associated with proximity can be the accelerators to undertake international collaboration, but at the same time potentially may impede collaborative activities. Widening non-spatial influences have hindered scholars from becoming involved in IRC activities (Muriithi *et al.*, 2018; Schurer, Dang-Xuan and Farag, 2019).

The examination of factors affecting collaborative research is broadly popular at a micro level (between researchers or institutions) and research has focused on identifying motivations behind the collaboration at meso level (between cities or sub-nationals) and macro level (between countries). These topics have historically been the subject of well-established review in Global North (GN) countries in an effort to accelerate their international academic cooperation. At the same time, research on similar topics is less prevalent in Global South (GS) countries since IRC activities are not as abundant there. Moreover, the specific topic of collaborative patents has been more predominantly investigated than the co-authored of papers. In addition, implementing variables of masses and distance between any two collaborative partners have been entrenched in the gravity model. Meanwhile elaborating the relation between two countries in economic cooperation, political framework and historical ties is less popular as a topic of discussion in the literatures. However, the aim of this chapter is to identify the determinant factors of international collaboration at regional level (group of countries) in the Association of Southeast Asia Nations (ASEAN) plus China, representing GS countries. This study specifically is going to estimate: a) How the mass of a country (represented by the volume of publications, population and income economies) determines the likelihood of undertaking international collaborative research; b) How geographical proximity influences

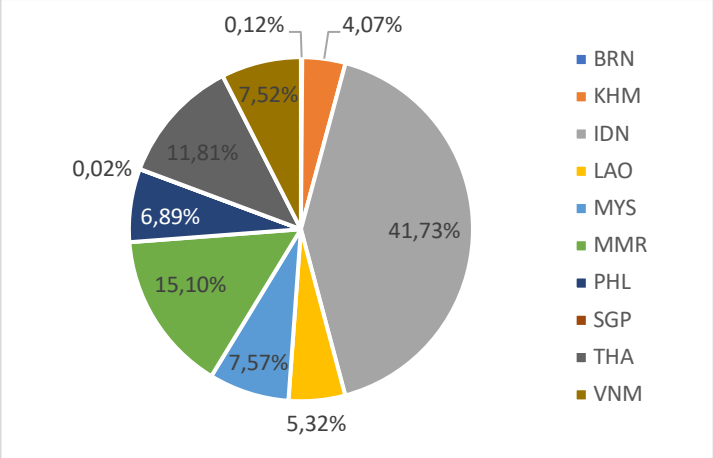
international collaborative research; c) How non-geographical proximity, such as historical relations (colonial ties), language similarity and similar membership determines international collaborative research in a regional organisation; and, d) How economic ties such as international trade influence the probability of undertaking international collaborative research. This chapter is organised into four main sub-chapters with a sequence as follows: introduction; the characteristics of ASEAN and China to explain size of country and international trade structure; findings of econometric results; and concluding discussion.

5.2. Characteristics of ASEAN and China

5.2.1. Country Size

Southeast Asia geographically consists of two main areas: a mainland region (called Indochina) where most of the ASEAN members are located, and a maritime region (previously known as Nusantara) as the major part (70%) (IMO, 2019). Ten out of 11 countries have joined ASEAN with only East Timor as a non-member of ASEAN located in Southeast Asia (Frost, 1990).

Among the ten members of ASEAN, Indonesia is the largest country (41.73% of total ASEAN area) with a land area of 1.8 million km^2, followed by Myanmar (0.6 million km^2) (see Figure 5.1). In contrast, Singapore is the smallest country with an area of only 709 km^2 (0.02%), while Brunei Darussalam's land area is six times greater than Singapore, making it the second smallest country (0.12%). Furthermore, a similar size (ratio to total ASEAN) is found between Malaysia (7.57%) and Vietnam (7.52%) as shown in Figure 5.1.



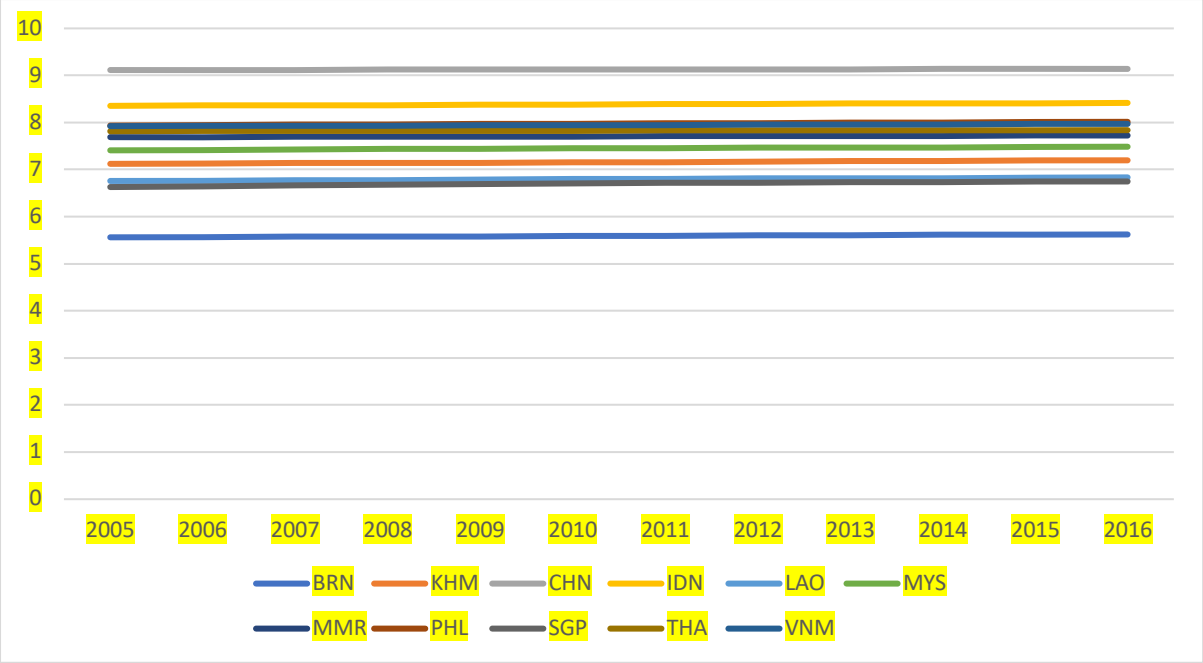
BRN: Brunei Darussalam, KHM: Cambodia, IDN: Indonesia; LAO: Laos, MYS: Malaysia, MMR: Myanmar, PHL: Philippines, SGP: Singapore, THA: Thailand, VNM: Vietnam

Source: Author

Figure 5. 1 Ratio land area of country members to ASEAN

Another variable used to measure the size of country is the population. ASEAN is home for more than 647 million people or about 8.6% of the global population. Meanwhile, ASEAN's population is less than half of China (1.38 billion). During the last two decades, the average growth of the ASEAN population is slightly higher (1.31%) than the world population (1.25%).

Among ASEAN member states (AMS), Indonesia has the biggest population (40.78% of total ASEAN). However, the size of the population exhibits a different pattern to the size of land area. For instance, Brunei Darussalam is the least populated country (0.07%), meanwhile Singapore (as the smallest area within ASEAN) has ten times a greater population than Brunei Darussalam (see Figure 5.2). This makes Singapore the densest populated country in ASEAN. Another contrast is presented by Myanmar (as the second largest land area) but it has a relatively small population (8.24%), while the Philippines, with a smaller area than Myanmar, has the second biggest population (16.21%).



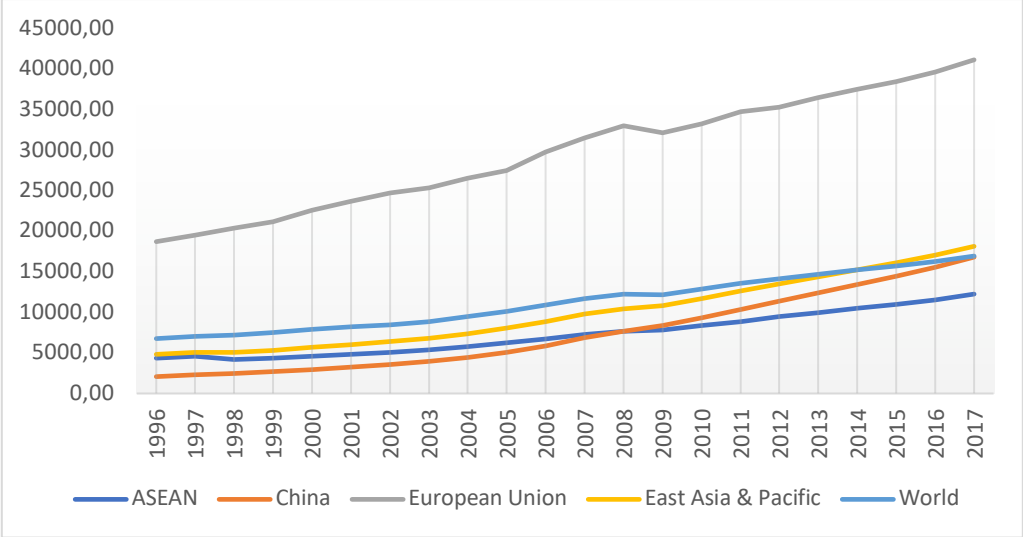
Note:
1) Population in log scale
2) BRN: Brunei Darussalam, KHM: Cambodia, IDN: Indonesia; LAO: Laos, MYS: Malaysia, MMR: Myanmar, PHL: Philippines, SGP: Singapore, THA: Thailand, VNM: Vietnam

Source: The World Bank, 2019

Figure 5. 2 Number of populations of AMS

5.2.2. GDP per Capita

ASEAN has been growing as an emerging economy from Asia. The Gross Domestic Product (GDP) per capita of ASEAN grew nearly three times in size over 21 years, from US$ 4,387.5 (in 1996) to US$ 12,253.2 in (2017). ASEAN has a greater annual growth of GDP per capita than the world but it remains lower than the world and East Asia Pacific (see figure 5.3). In the meantime, China demonstrates high annual growth of income per capita (10.51%) for 11 years (2000–2011) and resulted in growth more than eight times greater within two decades.

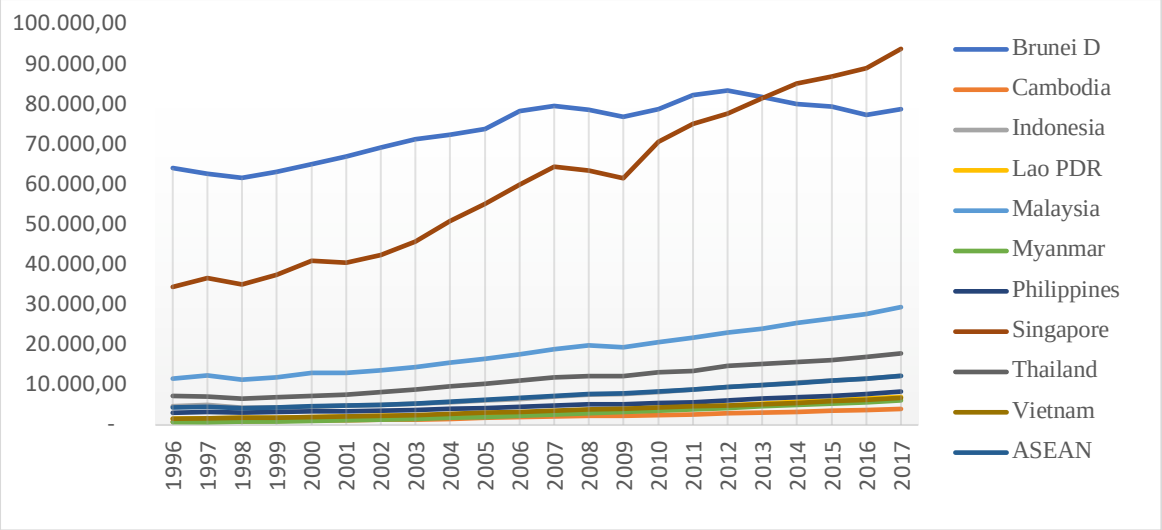


Source: The World Bank, 2019

Figure 5. 3 GDP per capita of ASEAN, China, EU and East Asia and Pacific, and World

Two most affluent countries have dominantly contributed to ASEAN GDP per capita for 65%. Singapore is the highest-income country (US$ 93,905) since 2014, followed by Brunei Darussalam (US$ 78,836) which previously had been the wealthiest country for the last 18 years (Figure 5.4). Meanwhile, Malaysia is the most improved member, reflected by its notable contribution to ASEAN from 8.9% (in 1996) to 11.5% (2017).

On the other hand, ASEAN encounters income per capita disparity between high-income and low-income countries which has not yet narrowed fundamentally in the last 21 years. For instance, the income disparity in 1996 was 98.82% and diminished slightly to 95.74% in 2017. In addition, half of AMS (Cambodia, Laos, Myanmar, Vietnam and Philippines) has an income per capita below ASEAN.



Source: The World Bank, 2019

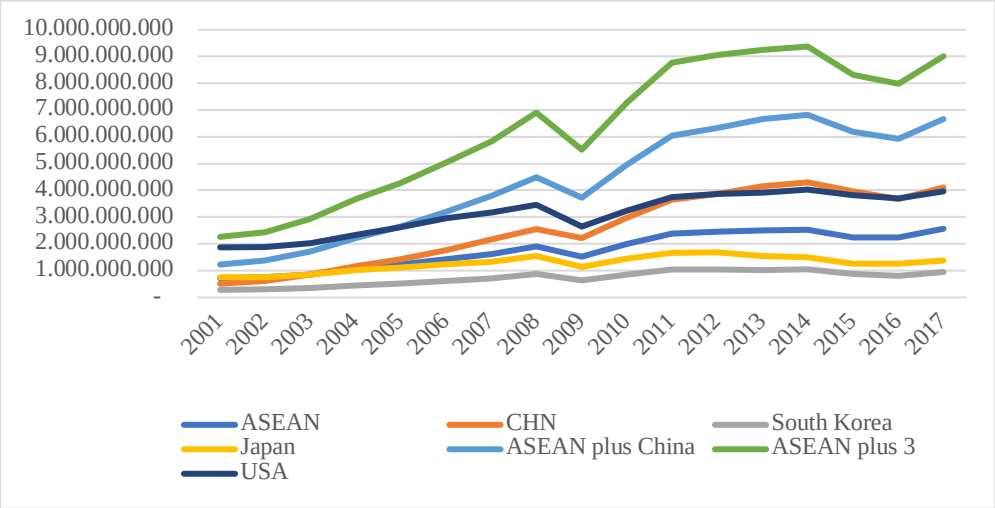
Figure 5. 4 GDP per capita of ASEAN members

5.2.3. International trade in ASEAN and China

ASEAN has been a new emerging region for two main reasons: it is located in-between two huge global market economies (China and India) and has a greater population and diverse labour force (Kobayashi *et al.*, 2017). In addition, the combination of a higher annual population growth, total population and continuous growth of GDP per capita make ASEAN a promising market in Asia. This potency was responded by launching the ASEAN Economic Community (AEC) on 31st December 2015.

AEC is a fundamental point for economic integration in ASEAN to accommodate an enormous market, valued at US$ 2.6 trillion with a population of more than 622 million (ASEAN, 2015). AEC was initiated after six years progress of ASEAN Plus Three (APT) as a framework in order to widen the intra-regional market and promote East Asian regionalism. APT is a mutual cooperation between ASEAN and neighbouring key countries like China, Japan and South Korea which institutionally developed in 1999 with the economy and financial cooperation as the main priorities (ASEAN, 2017).

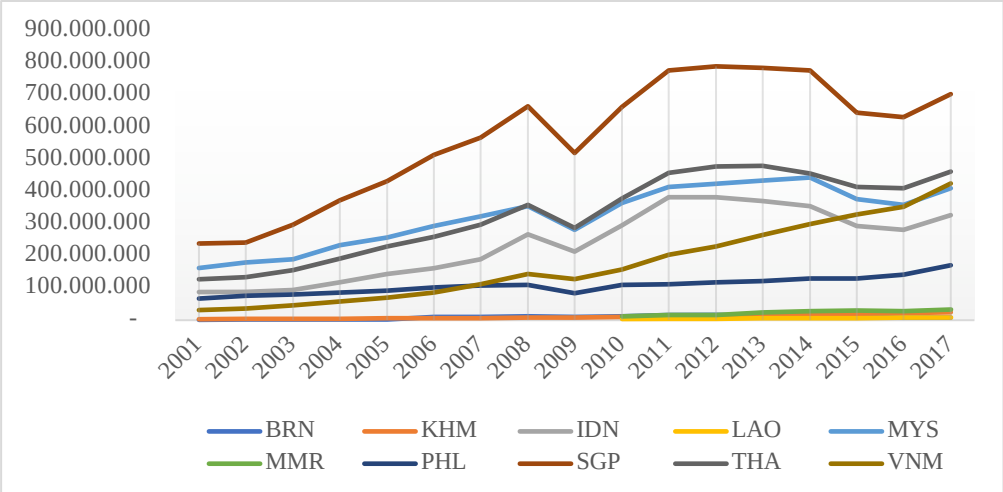
As seen in Figure 5.5, the total international trade (exports and imports) for ASEAN in 2017 stood at US$ 2.5 billion which grew more than three times during the period. The structure of international trade in ASEAN has been dominated by interregional trade (average 75.7%) which reflects a greater dependency on non-member countries. On the other hand, among countries in the APT framework, China has demonstrated an outstanding performance by expanding its total value eight times greater over 17 years with an annual growth of 15% which brought China to lead in Asia and global trade.



Source: UN COMTRADE, 2018

Figure 5. 5 Total international trade in ASEAN, China, US, South Korea and Japan

In the meantime, international trade among AMS exhibits more dynamic value. As seen from Figure 5.6, Singapore has been leading for international trade in the region (US$ 700.9 million) with the biggest share (27.3%), followed by Thailand (US$ 461.1 million). In contrast, four countries (Laos, Brunei Darussalam, Cambodia, Philippines) have trade values below the ASEAN average. It is interesting that Brunei Darussalam has the second highest GDP per capita but has a low international trade value reflecting an inward-looking national policy. Nevertheless, the trade value disparity among AMS has not much changed for 17 years which implies the presence ASEAN and AEC have not fostered intra-regional trade.



Notes: BRN: Brunei Darussalam, KHM: Cambodia, IDN: Indonesia; LAO: Laos, MYS: Malaysia, MMR: Myanmar, PHL: Philippines, SGP: Singapore, THA: Thailand, VNM: Vietnam

Source: UN COMTRADE, 2018

Figure 5. 6 Total international trade countries in ASEAN

5.3. Findings: Econometric Results

Undertaking IRC is motivated by internal factors which generate capacity within the country and external factors that come from outside a country. These sometimes are interchangeable, particularly when a relationship between countries is affected by separation factors, such as geographical distance, similarity of culture or language, historical ties, political bonding, and economic cooperation. Research identifying the determinant factors of international collaboration has been historically carried out in GN countries and results indicated a particular pattern. In the meantime, investigating factors conducive for IRC is essential to reveal how the pattern works in GS countries.

This study includes collaborative research within a region (ASEAN and China) and extra-region collaboration (a collaboration between ASEAN-China and non-ASEAN-china). Extra-

region involves collaboration with the most favorable countries (for example, United States, United Kingdom, Japan, Germany, Netherlands, Australia) and non-prominent countries, as explained in the previous chapter (Chapter 4). This chapter aims to diagnose how the factors influencing international collaboration in ASEAN and China since the region collaborate internally and externally.

The effect of the mass of the country and separation of countries on collaborative research will be estimated through the model as follows:

$$\gamma \mathrm{TCP}_{ijt} = \beta_0 + \beta_1 \mathrm{MASS}_{it} + \beta_2 \mathrm{MASS}_{jt} + \beta_3 PXM_{ijt} + \beta_4 IR_{ijt} + \varepsilon_{it}$$

Where $\gamma \mathrm{TCP}_{ijt}$ is the total collaborative research between country *i* and country *j* as a dependent variable, while $\beta_1 \mathrm{MASS}_{it}$ is the mass of country *i*, $\beta_2 \mathrm{MASS}_{jit}$ is the mass of country *j*, $\beta_3 \mathrm{PXM}_{ijt}$ is the proximity as separation between countries *ij*, $\beta_4 \mathrm{IR}_{ijt}$ is the international relations between countries *ij* and ε is the error term.

This study applies Geodesic distance collected from CEPII Research and Expertise on the World Economy databases. Geodesic distance is measured according to the great circle formula and employ latitudes and longitudes of the most prominent cities based on agglomerations of the population (Mayer and Zignago, 2006). The distance represents in km and accommodates across 225 countries.

Geodesic distance has been widely employed to measure bilateral cooperation since it estimates the shortest path between countries' main cities (Mayer and Zignago, 2011). In the meantime, most prominent international collaborators are situated in central cities with better infrastructures, administration processes, and access to knowledge sources (Yigitcanlar and

Muna, 2011). The country's central city tends to have more excellent international collaborations (Schubert and Glanzel, 2006; Maisonobe *et al.*, 2016). Thus, geodesic distance is appropriate to estimate determinant factor of international collaboration using gravity model.

Table 5.1 and Table 5.2 present descriptive statistics and the correlation matrix between variables. Two independent variables (total publications and international trade) show moderate correlation with the dependent variable (total collaborative papers), while the rest of the variables have a weak relation. In the meantime, the correlation between independent variables is mainly low and only trade has a moderate correlation to publications and population.

Table 5. 1 Descriptive statistics of variables

Variables	Mean	Std. dev	Coef. var	Min	Max
TCP_{ijt}	4.376	2.028	0.463	0.693	10.744
$ln PUB_{it}$	9.262	2.396	0.290	4.454	13.114
$ln PUB_{jt}$	10.685	1.568	0.147	4.736	13.398
$ln POP_{it}$	17.348	2.364	0.136	12.822	21.044
$ln POP_{jt}$	17.624	1.127	0.064	15.297	21.044
$ln GDPC_{it}$	9.503	1.147	0.121	7.590	11.400
$ln GDPC_{jt}$	10.276	0.726	0.071	7.590	11.400
$ln DST_{ij}$	8.516	0.910	0.107	5.935	9.635
$d LANG_{ij}$	0.259	0.438	1.690	0.000	1.000
$dMEM_{ij}$	0.417	0.493	1.184	0.000	1.000
$d COL_{i}$	0.208	0.406	1.950	0.000	1.000
$ln TRD_{ij}$	14.828	2.650	0.179	2.197	20.141

Source: Author

However, Tables 5.1 and 5.2 imply number of publications is closely associated with the total collaborations. In addition, international collaboration is stronger simultaneously with international trade which is reflecting internationalisation and experience within the global community. The volume of publications rate is higher when the population rate and GDP per capita are higher.

Table 5. 2 Correlation matrix between variables

		1	2	3	4	5	6	7	8	9	10	11	12
1	TCP_{ijt}	1.00											
2	$lnPUB_{it}$	0.62	1.00										
3	$lnPUB_{jt}$	0.47	0.05	1.00									
4	$lnPOP_{it}$	0.41	0.10	0.04	1.00								
5	$lnPOP_{jt}$	0.33	0.04	0.03	0.05	1.00							
6	$lnGDPC_{it}$	0.10	0.08	0.03	0.01	0.01	1.00						
7	$lnGDPC_{jt}$	0.30	0.09	0.13	0.09	-0.04	-0.05	1.00					
8	$lnDST_{ij}$	0.17	0.11	0.19	0.08	0.13	0.15	0.50	1.00				
9	$dLANG_{ij}$	0.12	0.12	0.18	0.09	0.13	0.03	0.02	-0.33	1.00			
10	$dMEM_{ij}$	-0.22	-0.13	-0.49	-0.11	-0.03	-0.03	-0.48	-0.83	0.24	1.00		
11	$dCOL_{i}$	-0.02	-0.09	0.11	-0.04	0.03	-0.03	0.04	0.19	0.01	-0.12	1.00	
12	$lnTRD_{ij}$	0.72	0.75	0.67	0.62	0.52	0.05	0.12	0.07	0.22	-0.11	0.00	1.00

Source: Author

The estimation data was tested using dispersion test (in AER's package in R), and the z value was 6.6627 with significance at 0.041 and dispersion value of 2.214228. A true dispersion occurs when the value is greater than 1. Therefore, to handle this condition, the model will be estimated using Negative Binomial regression and Poisson regression.

In order to investigate the effects of a country's characteristics such as the mass of the country, different elements of proximity and international trade as separation between countries, nine models were estimated using panel data Negative Binomial and Poisson regressions. Fixed effects (Country FE) have been applied to respond unobserved time-invariant characteristics of country and annual changes in scholarly outputs (Year FE).

Country fixed effects have been widely adopted to address multilateral trade resistance (MTR) in the gravity model that country *i* and country *j* individually encounter their trade activities with commerce partners (Anderson and van Wincoop, 2004; Adam and Cobham, 2007). In the context of IRC, MTR could be reflected as multilateral resistance to collaborate internationally with overseas collaborative research partners. The multilateral resistance generally associates

with economic variables, such as GDP and exchange rate, that tend to be bias regarding time (Adam and Cobham, 2007). To control for such resistance, I include country-pair FE. Also, elaborating the country fixed effects into the panel data estimation can accommodate specific national policy characteristics of each country that presume to influence the probability of undertaking international cooperation (UNESCAP, 2017).

The proposed model for estimation is the following:

$$\gamma ln\text{TCP}_{ijt} = \beta_0 + \beta_1 ln\text{PUB}_{it} + \beta_2 ln\text{PUB}_{jt} + \beta_3 ln\text{POP}_{it} + \beta_4 ln\text{POP}_{jt} + \beta_5 ln\text{GDPC}_{it} + \beta_6 ln\text{GDPC}_{jt} + \beta_7 ln\text{DST}_{ij} + \beta_8 \text{DLANG}_{ij} + \beta_9 \text{DCOL}_{ij} + \beta_{10} \text{DMEM}_{ij} + \beta_{11} ln\text{TRD}_{\text{ij}} + \mu_i + \mu_j + \mu_t + \varepsilon_{ijt}$$

Where: $\gamma ln\text{TCP}_{ijt}$ is the total number of co-authored papers for countries *ij* for years *t*; $\beta_1 ln\text{PUB}_{it}$ as total scholarly outputs or academic publications for country *i* for years *t*; $\beta_2 ln\text{PUB}_{jt}$ as total academic publications for country *j* years *t*; $\beta_3 ln\text{POP}_{it}$ as total population of country *i for* years *t;* $\beta_4 ln\text{POP}_{jt}$ as total population of country *j for* years *t*; $\beta_5 ln\text{GDPC}_{it}$ as Gross Domestic Product (GDP) per capita of country *i* for years *t;* $\beta_6 ln\text{GDPC}_{jt}$ as GDP per capita of country *j* for years *t*; $\beta_7 ln\text{DST}_{ij}$ is geodesic distance between countries *ij*; $\beta_8 \text{DLANG}_{ij}$ is dummy language similarity in countries *ij*; $\beta_9 \text{DCOL}_{ij}$ is dummy colonial ties in countries *ij* as proxy of historical relations; $\beta_{10} \text{DMEM}_{ij}$is dummy of political membership in ASEAN+3 between countries *ij*; $\beta_{11} ln\text{TRD}_{\text{ij}}$is volume of international trade between countries *ij* for years *t* and; μ_i and μ_j as dummy country *i* and dummy country *j*; and μ_t as dummy of year and; ε_{ijt} as error terms.

Since econometric results between Poisson regression and Negative Binomial regressions are identical, the analysis of this study focused on Negative Binomial due to several reasons: 1) the ability of Negative Binomial to handle dispersion in count data (Scherngell and Hu, 2011);

2) confidence intervals tend to be narrower; and, 3) has been widely used to estimate equations in the gravity model. Also, the overdispersion coefficients from the estimation in the family of Negative Binomial are generally significant. Thus, the Negative Binomial model is appropriate to estimate determinant factors of IRC in ASEAN countries and China.

The whole set of result estimation of the gravity model is presented in Table 5.3, and started with the estimation of the country's characteristics like the size of the population along with distance (first column), GDP per capita and distance (second column), publications and distance (third column), population with dummy language (fourth column), continuing with dummy colony (fifth column), dummy membership (sixth column), and trade (seventh column). Finally, all independent variables were introduced simultaneously into an integrated model in the two last columns: with FE (eight column) and non-FE (ninth column). Except for the last column, all estimations have included year dummies to control the dynamics of change of the period, unobservable factors which generally appear over countries and country dummies (*i* and *j*) to control for unobserved characteristics of the host country (*i*) and collaborator country (*j*) like national regulations, specific policies and strategies for research and education that we cannot directly observe.

Among three variables of country's characteristics, only GDP per capita and publications have passed the significance test. The effect of GDP per capita is negative to collaboration which implies increasing the income per capita will vigorously diminish the interest to undertake international collaboration. Meanwhile, publications positively affect IRC which means expanding the volume of scholarly outputs will raise the likelihood of collaborating internationally.

Table 5. 3 Regression result Negative Binomial country FE and year FE, 2006-2016

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
lnPOP$_{it}$	-0.02			0.02	0.02	0.02	0.02	-0.01	-0.02	0.01
	(0.04)			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.02)
lnPOP$_{jt}$	-0.02			-0.02	0.02	0.02	0.05	-0.79	-0.81	0.02
	(0.59)			(0.59)	(0.59)	(0.59)	(0.59)	(0.65)	(0.03)	(0.03)
lnGDPC$_{it}$		-0.37**						-0.33**	-0.55*	-0.01
		(0.16)						(0.17)	(0.20)	(0.03)
lnGDPC$_{jt}$		-0.35**						-0.12*	-0.14*	-0.04
		(0.26)						(0.33)	(0.05)	(0.06)
lnPUB$_{it}$			0.16***					0.13**	0.17**	0.12****
			(0.06)					(0.06)	(0.01)	(0.01)
lnPUB$_{jt}$			0.20**					0.26**	0.31**	0.18****
			(0.08)					(0.10)	(0.03)	(0.03)
lnDST$_{ij}$	-0.13***	-0.13***	-0.13***					-0.10**	-0.15**	-0.13****
	(0.04)	(0.04)	(0.04)					(0.04)	(0.03)	(0.03)
dLANG$_{ij}$				0.05				0.03	0.02	0.05*
				(0.04)				(0.04)	(0.02)	(0.03)
dCOL$_{ij}$					0.06			0.07*	0.06	0.07**
					(0.04)			(0.04)	(0.03)	(0.03)
dMEM$_{ij}$						0.14*		-0.09	-0.04	-0.01
						(0.08)		(0.08)	(0.06)	(0.05)
lnTRD$_{ijt}$							0.04**	0.03*	0.04**	0.03****
							(0.02)	(0.02)	(0.03)	(0.01)
Constant	1.84	2.20	-1.20	0.66	0.73	0.75	0.68	15.67	16.71	-0.34
	(10.05)	(3.25)	0.97	(10.05)	(10.05)	(10.04)	(10.05)	(10.85)	(10.96)	(0.94)
R^2 (%)	88.92	89.26	89.68	88.40	88.41	88.52	88.85	96.05	85.27	81.95
R^2 adj (%)	88.63	88.98	89.41	88.10	88.11	88.22	88.57	95.61	84.12	80.83
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Country Pairs-FE	No	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Over dispersion	3.17*	3.32**	3.35**	2.11	2.32	2.27	3.14*	3.42**		3.31**
No. Obsv	1584	1584	1584	1584	1584	1584	1584	1584	1653	1584

Variance inflation factor (VIF) value is ranging from 3.1 to 11.3 that implies low multicollinearity.
Correlation between variables is less than 0.80 which represent low correlation.
Robust standard errors are reported in parentheses.
**** p<0.001; *** p<0.01; ** p < 0.05; *p < 0.1

Source: Author

Furthermore, proximity variables lead to various results. The effect of geographical proximity has been consistent across five different models which is negatively significant. This indicates geographical factors fundamentally impede collaboration between countries. The negative effect of geographical proximity on knowledge flows within the region is relatively low as compared with similar studies at regional level – exercising different measurement of knowledge flows in Europe (Ponds, van Oort and Frenken, 2007a; Scherngell and Barber, 2009; Hoekman, Frenken and Tijssen, 2010a; Scherngell and Hu, 2011; Quatraro and Usai, 2016).

Besides, the study needs to estimate the effect of distance using non-linear regression to anticipate an inelastic transport cost over time (Coe *et al.*, 2002; Croce, Juan-Ramón and Zhu, 2004). Variable distance also influences the other factors, such as culture closeness, similar country's history or policies, that can affect the degree of relation between countries (Márquez-Ramos, Martínez-Zarzoso and Suárez-Burguet, 2007). The effect of non-linear distance is in a function of $Y = 2.9654x^{0.9386}$ in $R^2 = 30\%$. The result is close to the function of $Y=Kx^1$, which is a linear function. Therefore, estimating using the linear gravity model is appropriate to measure the effect of distance in determining IRC in ASEAN and China.

In the meantime, historical ties display positive and significant effects through the simultaneous model (8). This implies colonial ties between GS countries and GN countries do exist and have been maintained in various forms of cooperation, and one of them manifested in academic collaboration. The result confirms previous studies, which highlighted that having similarity in historical ties between two countries tend to strengthen collaboration and easing knowledge flows between them (Sooryamoorthy, 2009). On the other hand, in a simple estimation (model

6), dummy membership in ASEAN is positive and significant as expected. This confirms the presence of an intergovernmental organisation in the region has been easing cooperation between members if there is no other factor involved except the country's characteristics. The dummy language has not passed the significance test both in a simple FE model and simultaneous FE model.

International relations between countries represented by trade gives positive and significant effects on collaborative research for both FE models (7 and 8). This corroborates transnational trade promotes collaborative research between countries. Economic cooperation may generate other cooperation able to directly strengthen economic relations.

This study also elaborates the control group of country pairs without any research collaborations in model 9 (Tabel 5.3). The control group has been estimated using the ZINB (Zero Inflated Negative Binomial Model) with pscl package in R since the model can handle overdispersion and zero counts. ZINB model demonstrates slightly different to Negative Binomial model. Variable publications (as a proxy of country mass), GDP per capita, distance and trade can explain the probability of IRC in ASEAN and China.

In order to analyse whether the explanatory variable behaves differently determining the independent variable, sensitivity analysis is undertaken through country pairs (*ij*) fixed effects. The specification model for country pairs fixed effects and year fixed effects is arranged as below:

$$\gamma ln\text{TCP}_{ijt} = \beta_0 + \beta_1 ln\text{PUB}_{it} + \beta_2 ln\text{PUB}_{jt} + \beta_3 ln\text{POP}_{it} + \beta_4 ln\text{POP}_{jt} + \beta_5 ln\text{GDPC}_{it} + \beta_6 ln\text{GDPC}_{jt} + \beta_7 ln\text{DST}_{ij} + \beta_8 \text{DLANG}_{ij} + \beta_9 \text{DCOL}_{ij} + \beta_{10} \text{DMEM}_{ij} + \beta_{11} ln\text{TRD}_{\text{ij}} + \mu_{ij} + \mu_t + \varepsilon_{ijt}$$

The estimation results of country pair FE and year FE are reported in Table 5.4. Country-pair FE produces different results compared to country FE (table 5.3). Regression outputs demonstrate only GDP per capita and publications significantly affect the collaborative research which are stable over different conditions. These imply characteristic of bilateral cooperation (countries *ij* relation) has influenced GDP per capita and publications as the important factors for undertaking research collaborations. Meanwhile separation variables (*ij*) cannot be estimated using country-pairs FE. In other words, it suggests GDP per capita, and publications are the prominent factors determining IRC for both country FE and country-pairs FE estimations.

Besides, a control group of country pairs without any research collaboration has been elaborated in model 19 in table 5.4 (as has applied in model 9 table 5.3). The estimation result presents similar with Negative Binomial (model 18), but only publications positively significant determining IRC in ASEAN countries and ASEAN. Also, the findings model 19 support model 9 (table 5.3) that only GDP per capita can explain the probability to undertake IRC.

Table 5. 4 Negative Binomial with country-pairs FE and year FE, 2006–2016

Variable	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19
lnPOP$_{it}$	0.01			0.01	0.01	0.01	0.01	-0.01	-0.01
	(0.04)			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)
lnPOP$_{jt}$	-0.02			0.02	0.02	0.02	0.04	-0.78	-0.67
	(0.59)			(0.60)	(0.59)	(0.59)	(0.59)	(0.65)	(0.55)
lnGDPC$_{it}$		-0.37***						-0.33*	-0.35
		(0.16)						(0.17)	(0.18)
lnGDPC$_{jt}$		-0.34***						-0.13*	-0.17
		(0.26)						(0.33)	(0.35)
lnPUB$_{it}$			0.16***					0.13**	0.12**
			(0.06)					(0.06)	(0.08)
lnPUB$_{jt}$			0.20**					0.26**	0.24**
			(0.08)					(0.10)	(0.11)
lnDST$_{ij}$	0.55	-0.32	-0.09					0.68	0.72
	(1.26)	(0.40)	(0.25)					(1.41)	(1.96)
dLANG$_{ij}$				0.03				0.07	0.12
				(0.35)				(0.35)	(0.23)
dCOL$_{ij}$					-0.15			-2.39	-1.15
					(0.56)			(1.85)	(1.17)
dMEM$_{ij}$						0.63		0.23	0.11
						(0.56)		(1.06)	(0.45)
lnTRD$_{ijt}$							0.03	0.03	0.07
							(0.04)	(0.04)	(0.09)
Constant	-3.54*	3.97	-1.33	1.01	1.05	1.05	0.91	9.51	9.77
	(1.82)	(5.49)	(1.78)	(10.06)	(10.05)	(10.05)	(10.05)	(6.31)	(7.41)
R^2 (%)	95.27	95.64	96.04	95.26	95.27	95.26	95.31	96.38	80.31
R^2 adj (%)	94.75	95.17	95.61	94.74	94.75	94.75	94.80	95.97	79.81
Country FE	No	No	No	No	No	No	No	No	No
Country Pairs-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Over dispersion	4.19*	4.21**	4.26**	3.07	3.24	3.12	4.07	4.38*	
No Obsv	1584	1584	1584	1584	1584	1584	1584	1584	1653

Robust standard errors are reported in parentheses.

**** p<0.001; *** p<0.01; ** p < 0.05; *p < 0.1

5.4. Concluding Discussion

Literature on IRC has been growing widely as it is a fundamental research area in economic geography. Discussion of the importance and advantages of collaborative research has brought further consideration about the drawbacks in undertaking the cooperation, like the costs and effort related to the process. Gaining benefits and encountering difficulties in the process involved are influenced by the pattern of proximities that have been highlighted in many previous studies. This study adopts a gravity model approach to analyse the variation of cross-country collaborative research in ASEAN and China through co-authored of papers.

The results present valuable insights in the context of empirical and theoretical evidence for international collaborative research at a regional level in Southeast Asia. *First,* between three variables as a proxy of a country's characteristics, only GDP per capita and the total volume of publications determine IRC. The number of publications can be push and pull factors in collaboration. Countries with higher knowledge production are seen as more attractive as sources of external knowledge since they have most recent research reflecting more advanced knowledge. High-ranking universities are generally associated with well-established research quality and publications due to publications being awarded as a prominent dimension (weighted 30%–60%) in global university measurements by the Times Higher Education, QS World University Ranking, Top Universities and Centre for World University Ranking (CWUR). The total number of scholarly publications also demonstrates academic productivity which is conducive in promoting collaboration. In the meantime, countries with low capacity are encouraged to undertake international collaboration to acquire the newer and advanced knowledge which cannot be obtained internally. Furthermore, having greater scholarly outputs has motivated a country to keep seeking different knowledge externally in order to produce new

knowledge. Co-authored papers have been cited in greater numbers than single-authored publications that implies collaboration increases research quality. In other words, undertaking IRC potentially benefits strengthening academic knowledge quality and leveraging the volume of publications.

As representing the wealth of country, GDP per capita confirms the hypothesis. Greater GDP per capita is associated with adequate funding which is conducive to research activities. Therefore, high-income countries are able to do more complex and advanced research because the researchers have been facilitated with sufficient resources. As a result, the situation potentially leads to researchers being reluctant to collaborate externally when undertaking international collaboration has resulted in smaller incentives than they have received for research collaboration within the country. This finding has extended previous studies which estimated country to country collaboration in ASEAN (Gholizadeh *et al.*, 2014) and China (Bai and Liu, 2016). Moreover, the research finding also corroborates the paradigm of undertaking IRC to seek external funding and research facilities. Researchers in low-income economy countries are generally confronted with budget limitations and insufficient equipment, data and resources (Li, Liao and Yen, 2013), while international collaboration is possibly bridging surplus research resource countries with limited research resource countries.

On the other hand, population does not seem to give a significant effect on probability to collaborate with global scholars. The size of the population does not always reflect the number of researchers who are capable of producing academic papers, while the varying scientific capacity of individuals is presumed to result in differing engagement with international scholars. The population size does not affect the probability of collaboration since collaboration

is more influenced by the academic level as a representation of knowledge capacity. This is in line with collaborative research at the level of firms in sectors of innovation (patents), both in developing countries and developed countries (Alnuaimi, Singh and George, 2012; Schmiele, 2012) and information and communication technology (ICT) industries (Grillitsch, Tödtling and Höglinger, 2015).

In addition, countries with greater numbers of population somehow have lower performance both in terms of scholarly outputs and co-authored papers. For example, the population of Indonesia in 2016 was 47 times greater than Singapore but could only produce half the number of collaborative papers compared to Singapore. Similarly, Malaysia with a population size of only one third of the Philippines, published nearly ten times the number of co-authored papers. A relation between numbers of population and collaborative research papers implies a wide disparity of human resource quality between ASEAN member states (AMS).

Second, geographical factors and historical ties are the only factors related to proximity that determine IRC in ASEAN and China. Greater distance may reduce the probability of having face-to-face meetings more frequently due to the cost and time involved in travel. Meanwhile during the collaborative work, researchers need to meet at least for two main agendas: coordination (includes applying for research grant) and presenting the results (either through conferences or reporting to research sponsor). On the other hand, budget allocation for travel (for meetings, reporting and attending conferences) generally is limited by the sponsor for particular circumstances.

However, a significance of geographical proximities in ASEAN brings some reflections. Technology and transportation infrastructures in ASEAN seem poorly developed. As well as a disparity of income in terms of economy, ASEAN encounters a wide disparity on infrastructure development among the members, particularly for communication and transportation which interlink within ASEAN and neighbouring countries (Sombatsompop *et al.*, 2011; Gholizadeh *et al.*, 2014). Meanwhile, as a region ASEAN comprises of archipelagic countries where infrastructures are essentially required to accelerate interconnectivity between countries.

The historical ties seem fundamental in interlinking GS countries to GN countries, particularly between the colonies and mother colony country. The ties may not be as strong as economic relations, but they have been continuously maintained through diverse cooperation, like education and culture, technology and innovation, and research collaboration. One example is seen from the historical relations between The Netherlands and Indonesia over the last 400 years. Education and research cooperation between these two are manifested by the NWO (the Dutch research council) providing a research fund for Indonesian scholars;[3] the scientific programme Indonesia–Netherlands;[4] various independent collaboration activities between universities from both countries;[5] an exchange programme for engineers;[6] and a support scheme

[3] NWO and the Indonesian Ministry of Research Technology and Higher Education (RISTEKDIKTI) are supporting collaborative research between the Netherlands and Indonesia through providing a research fund for research in renewable energy, social sciences, humanities, engineering and natural sciences (https://www.nwo.nl/en/funding/our-funding-instruments/wotro/merian-fund/cooperation-indonesia-the-netherlands/cooperation-indonesia-the-netherlands.html).
[4] Scientific programme run by The Royal Netherlands Academy of Arts and Sciences for Indonesia with particular agendas: providing research grants, collaborative research projects, visiting professor (https://www.knaw.nl/en/international/scientific-cooperation-with-indonesia).
[5] Some examples are: Leiden-Indonesia (https://www.universiteitleiden.nl/en/dossiers/indonesia), Twente Universities and Wageningen University and Research (WUR) (https://www.wur.nl/en/newsarticle/Relation-between-Indonesia-and-WUR-was-defining-for-development-cooperation-1.htm).
[6] Exchange programme for engineers initiated by foreign minister of the Netherlands and Indonesia in 2013 (https://www.government.nl/latest/news/2013/02/21/the-netherlands-and-indonesia-to-step-up-cooperation).

in scholarships, internships, short courses and student exchanges in the Netherlands.[7] This finding has addressed a result in the previous chapter (4) about the role of colonial ties in the development of community relations. Nevertheless, historical proximity is not as strong as geographical proximity for the coefficient and degree of significance. The colonial era brought poignant experiences for the colonies and had encouraged them to lessen the domination of the colonial system within their countries. By the time several ASEAN countries had developed their economy and widened international cooperation with other countries they may have reduced their dependency on the mother colony. This result is confirmed by other studies that ASEAN countries generally have low dependency on mother colony countries (Nagtegaal and De Bruin, 1994; Boshoff, 2009).

On the other hand, two aspects of proximity (membership in APT and language) do not affect the likelihood of undertaking international collaboration. ASEAN as a regional organisation is driven by a social-political security approach instead of economic motivation. As the result, ASEAN encounters several challenges in regard to regional cooperation like: a slow process on regionalism and economic integration due to the absence of Custom Unions and a Monetary Union, the lack of regional authority as a commission board, leadership issues and slow building of institutions has impacted on less cooperation between members (Kim, 2012). In addition, a wide gap in academic capacity (Fizzanty and Hidayat, 2018) and research infrastructure are experienced by most AMS (Sombatsompop *et al.*, 2011), while, the presence of the ASEAN University Network (AUN) has been focused on graduate exchange and migration rather than fostering collaboration between universities in ASEAN. Furthermore, the

[7] This program is managed by Nuffic Neso for human resource development in Indonesia with particular program for education, internship and student exchange (http://www.nesoindonesia.or.id).

performance of the ASEAN Committee on Science and Technology (ASEAN-COST) is still far from what is expected in order to facilitate collaboration. Moreover, as an archipelagic region, ASEAN comprises more than 1000 languages across ten members, with English as the working language. A similar language is only spoken between a few members (with spatial closeness of neighbouring countries), such as Indonesia, Malaysia, Singapore, and Brunei Darussalam. In the meantime, collaborative research with foreign scholars is a process of internationalisation of individuals, institutions and knowledge that is mostly delivered in English. This implies language similarity is more likely easing collaboration at a smaller scope (with homogenous culture) than the global community. In addition, language similarity helps foster collaboration if it is followed by migration flow (Montobbio and Sterzi, 2013). Unfortunately, migration flows in ASEAN are relatively low compared to other regions like European regions due to the slow process of regionalism in ASEAN.

Third, economic cooperation through trade has facilitated transnational collaborative research. Research activities require laboratory equipment, machinery and raw material that in certain situations cannot be found within a country, and all of these may be obtained through international trade. For instance, collaborative research undertaken in GS countries to mitigate natural disasters while most of the advanced technologies would need to be imported from GN countries. Another example is collaborative research for sustainable food or tropical diseases conducted in GN countries where the demand is to provide a research environment similar to tropical countries. Moreover, at a practical level, some MNCs undertake research collaboration with local universities in foreign countries to expand the market in the other countries and grow national innovation. For example, research between Toyota (from Japan) and six universities

in Indonesia to develop low carbon emission vehicles (LCEV) and the hybrid cars;[8] and collaboration between MNC and the National University of Singapore[9] (Kam, 2010).

To sum up, IRC in ASEAN and China draws on a different pattern of proximities than generally occurs in GN countries due to spatial characters and some disparities in ASEAN and China. The country's characteristics possibly work in different ways to determine collaboration and not all indicators directly associate with probability to undertake IRC. Geographical factor is still crucial hampering probability to pursue IRC. Nevertheless, although various factors exist, international collaboration should be regarded as a scientific ground. This study has contributed to the perspective on academic knowledge by extending previous studies on determinants of international collaboration from countries in Southeast Asia's perspective as representative GS countries. Analysis at regional level (group of countries) of the specific country's characteristics may emphasise the importance of colonial ties for most GS countries in Southeast Asia in international academic cooperation with the prominent countries in GN. Knowledge production and economic dimensions are correlated, and have been addressed using a quantitative approach, represented by international trade and GDP per capita. Furthermore, the impact of knowledge flows through collaborative research will be examined further in the next chapter (6).

[8] Research collaboration between Toyota and universities in Indonesia facilitated by Ministry of Research and Technology and Higher Education to promote national innovation since 2012 (https://otomotif.tempo.co/read/1103517/kemenperin-toyota-kolaborasi-riset-teknologi-mobil-listrik).
[9] Collaborative research between MNC and NUS conducted in various different sectors, for example with GE Water for water and process technologies, Hollywood studios for media and entertainment laboratory, and with other MNC in medical and health sector.

CHAPTER VI

THE IMPACT KNOWLEDGE FLOWS ON INNOVATION GENERATION

6.1 Introduction

Innovation has been a crucial element in economic development, particularly for improving national productivity. Many nations promote innovation as one of their priorities in national policies to encourage competitiveness since innovation involves a learning process and leveraging capacity for human resources, institutions and national systems (Park, 2001). For example, in European regions, innovation has been selected as one of the policy priorities to accelerate development since innovation brings effects that increase industrial productivity, profits and total outputs (Eurostat, 2016). Also, global competition continuously demands something new, fresh and extraordinary of products, approaches or technologies, while innovation is expected to answer these challenges through the benefits from implementing innovation in productive sectors (Nieto and Lluis, 2007). Advantages from innovation are in at least (but not limited to) three main dimensions: better, cheaper, faster, or popularly known as the BCF model (Tiwari and Buse, 2007). Innovation affects the production outputs by providing a better quality of product or service with lower prices to achieve higher sales in the market.

The advantages of innovation are mostly seen at the micro level when it improves the production system that can directly affect efficiency and productivity elements. Innovation provides the possibility of conducting a flexible production process and encouraging a greater diversity of product through innovative methods (process) and technology (Eurostat, 2008), leading to productivity improvement (Ramadani *et al.*, 2017). Therefore, increasing

productivity and competitiveness at micro (firms) level will aggregately influence a country's productivity and competitiveness, in a move towards national growth and development. In the other words, innovation will lead to economic growth and development at the country level (Jalles, 2010; Nilsson, 2013).

Since innovation stimulates economy and development, it is important to measure the performance of innovation. Assessing innovation helps to contribute to policy design for development, both at national and sub-national level (Litan, Wyckoff and Fealing, 2014). In addition, innovation is one the effective methods to estimate the demand for investment in research and development (R&D) and human resources which support the economy and development (Howells, 1990; Heng *et al.*, 2012; Ferreras-Méndez *et al.*, 2015). Meanwhile, analysing performance helps to define collaborator partners which can significantly determine advantages from collaborative research (Nilsson, 2013).

Generating innovation involves a complex process from a combination of various inputs. The process to create innovation is dominated by intensive research activity (as the core element of innovation) and followed by other elements such as markets and sales (as drivers and targets of innovation), commercial and financial systems (as research funding), production processes where innovation is implemented, and resource and supply (Schumpeter, 1983). In the meantime, besides human resources and capital as factors of production inputs, innovation mainly depends from knowledge.

In fact, not every country has sufficient knowledge capacity to innovate (Fischer, 2001; Popadiuk and Choo, 2006; Ponomariov and Toivanen, 2014b; Cruz-Gonzalez, Lopez-Saez and

Navas-Lopez, 2015). Acquiring external knowledge has been pursued by many countries, either to leverage knowledge capacity and/or complement internal knowledge that may be difficult to produced endogenously (Decaroils and Deeds, 1999; Erden *et al.*, 2014). However, collaborative research is seen as the most favourable channel (Melin, 2000; Gertner, Roberts and Charles, 2011; Kafouros *et al.*, 2015) among other knowledge flow mechanisms (foreign direct investment, international trade, international migration (Fagerberg, Srholec and Verspagen, 2010; Cappelli and Montobbio, 2014; Lengyel and Leydesdorff, 2015; Lengyel and Eriksson, 2017). Several advantages can be obtained from undertaking research collaboration in order to acquire knowledge externally, like an opportunity to learn technical aspects, a sustainable knowledge exchange, and maintenance of links with collaborative partners, and generating further cooperation like investment, trade, and non-economic cooperation.

Collaborative research has been popular globally for more than two centuries and has been undertaken in various topics. At the beginning, identifying motivations behind research collaboration at micro (individual and institutional), meso (sub-national, cities) and also macro (country) level was prevalently undertaken by many scholars and continuously grows to date (Georghiou, 1998; Storper and Venables, 2004; Jeong, Choi and Kim, 2014). In addition, the analysis of collaborative research is not limited to national level only, but has expanded into a broader scale by involving multilateral countries and groups of countries in relations, like Global North (GN) countries and Global South (GS) countries, South-South relations and North-North relations (Arunachalam and Viswanathan, 2008; Holmarsdottir *et al.*, 2013; Jeffery, 2013; Collyer, 2016). Nonetheless, other issues have risen related to cooperation between GN countries and GS countries, particularly with regard to unequal advantages and

how to promote mutual collaboration for both sides as the main agenda in collaboration (Hall, 2002; Jentsch and Pilley, 2003; Johnson and Wilson, 2006; Tierney *et al.*, 2013).

However, this study aims to estimate the impact of collaborative research (as reflected in co-authored papers) on innovation at regional level (group of countries), by differentiating the source of knowledge flows: intra-regional collaborative research (within region) and interregional collaborative research (collaboration with countries beyond the region). Distinguishing between the two different types of knowledge flow is expected to provide evidence of an indication of unequal collaboration between GN countries and GS countries. This chapter is organised as follows: introduction, description of the variables, statistic and correlation, model specification, estimation results of regression model, and concluding discussion. The result will not be interpreted as causal relation.

6.2 Description of the Variables

Innovation is fundamentally generated from knowledge accumulation then transformed into new technologies, new methods, new products, new services and new systems that bring economic advantages. Besides knowledge as the main source of innovation, there are other elements as input for processes producing innovation like human resources, sufficient funding to finance R&D activities, international trade and foreign direct investment (FDI) as part of the knowledge transfer instruments, education expenditure, number of labourers, and GDP per capita (Porter, Stern and Furman, 2002; Hsu *et al.*, 2015; Smit, Abreu and de Groot, 2015; Rosenzweig, 2017; Zemtsov *et al.*, 2017; Abdu and Jibir, 2018). Measuring the impact of international research collaboration (IRC) on innovation performance is substantially important

to confirm how IRC brings advantages for GS countries, while on the other side it has been extensively studied in GN countries.

Patents have been selected as the proxy of innovation due to several considerations: 1) they are a well-established indicator and have been implemented broadly in many countries (Griliches, 1990b; Alca and Gittelman, 2006); 2) the capacity to record innovation with a stable standard assessment that awards inventions as innovation over the years; 3) the most inclusive and specific measurement to document inventions (Kleinknecht, Montfrort and Brouwer, 2002); 4) the most appropriate measurement for performance comparison either between individuals (micro) or between countries (macro) level analysis (Hagedoorn and Cloodt, 2003); 5) it is possible to trace utilisation of patents and the impact of innovation through patent citations; 6) availability of database and globally standardised measurement; 7) implies production of new knowledge in contrast with existing knowledge (Rogers, 1998) and originality of innovation to support competitiveness (Hsu *et al.*, 2015). Patents data for this study was collected through the World Intellectual Property Right (WIPO) website for 11 years (2006–2016) duration.

On the other hand, employing patents to measure innovation performance has some potential drawbacks, for example the limitation to capturing most of the innovations since some firms are likely to keep their inventions instead of registering them as patents to prevent their competitors from imitating their ideas (Kafouros *et al.*, 2015; Bai and Liu, 2016; Chen, Liu and Ma, 2017). Furthermore, the engagement rate of applying for patents varies across countries due to differing intellectual property right (IPR) protection, different technological intensity, complexity of the patenting process, and the high cost of application procedures (Kleinknecht, Montfrort and Brouwer, 2002). On the other hand, patents do not necessarily represent the

commercialising of innovation since in some cases patents are not applicable to industry needs. Nevertheless, apart from the limitations, patents are appropriate as representing innovation because of ability to officially record inventions for certain period, worldwide accepted as innovation measurement and as manifesting novelty of knowledge creation.

In the meantime, external knowledge is pivotal for stimulating activities for innovation generation (Edquist and Hommen, 2008; Zanello *et al.*, 2016a; Cammarano *et al.*, 2017). Collaborative research has been employed globally to acquire external knowledge, besides the other advantages from collaboration such as technical assistance, sharing of materials and equipment, research funding and widening academic networks. Collaborative research has been categorised as intra-regional and interregional in respect of estimating the benefits of knowledge flows for GS countries.

Collaborative research is estimated simultaneously with control variables due to activities for generating innovation being influenced by other factors. Control variables have included in the vector covariance, for instance government support for IPR protection and providing conducive business climate, degree of openness for international relations and technological intensity are examined along with collaborative research (Kafouros *et al.*, 2015; Bai and Liu, 2016). International trade (Porter, Stern and Furman, 2002; Rosenzweig, 2017) and FDI are associated with a country's internationalisation and international experience which are found to be strongly correlated with innovation in 32 countries in Europe (Filippetti, Frenz and Ietto-Gillies, 2011) and in 40 global countries with a combination of low and high technological capacity (Filippetti, Frenz and Ietto-Gillies, 2017). While human capital (Wu Jyun-Yi and Hsu Chih-Chiang, 2008; Lee, Florida and Gates, 2010), R&D spending (Zemtsov *et al.*, 2017) and the

quality of human capital (Smit, Abreu and de Groot, 2015) are also seen as other crucial factors driving innovation activities.

However, estimating the effect of explanatory variables altogether with control variables on innovation has a potential risk of endogeneity. Endogeneity arises when explanatory variables may be affected by dependent variable or another situation when both independent and dependent variables altogether may be affected by unobserved variables (Esping-Andersen and Przeworski, 2001; Conbes and Gobillon, 2015). A model with endogeneity inhibits the generation of causal claims and affects the biased measurement. Making a difference of each variable (by applying lagged time to explanatory variables) can be done in order to partially addressing the endogeneity problem in panel regression (Qian, 2014). A lagged one-year has been proposed into explanatory variables and control variables.

6.3 Data Statistics and Correlation

Descriptive statistics and a correlation matrix for contemporaneous variables and lagged one-year variables are presented in Tables 6.1, 6.2 and 6.3 respectively. Contemporaneous variables show that explanatory variables are closely correlated to the dependent variable innovation as well as between explanatory variables. Meanwhile, the correlation values among control variables are relatively low.

Table 6. 1 Descriptive statistics contemporaneous variables and lagged one-year variables

	Variables	Mean	Std.dev	Coef.var	Min	Max
1	PTN_{it}	72,932	229,638	3.15	10	1,338,503
2	$INTRA_{it}$	1,249	1,506	1.21	13	7,163
3	$EXTRA_{it}$	13,484	28,525	2.12	58	151,963
4	$TRDr_{it}$	0.45	1.14	2.55	0.01	4.53
5	$EDUr_{it}$	3.45	1.19	0.34	1.51	6.66
6	$R\&Dr_{it}$	0.77	0.75	0.97	0.06	2.60
7	LAB_{it}	117,059,434	238,812,882	2.04	179,290	789,149,173
8	$GDPcap_{it}$	24,781	28,863	1.16	1,972	89,103
9	FDI_{it}	34,260,927,090	67,802,709,614	1.98	87,839,128	291,000,000,000
10	$BUSenv_{it}$	68.62	18.12	0.26	23.72	96.49
11	$INTRA_{it-1}$	1,323	1,552	1.173	16	7,163
12	$EXTRA_{it-1}$	14,283	29,624	2.074	58	58
13	$EDUr_{it-1}$	3.48	1.20	0.35	1.51	1.51
14	$TRDr_{it-1}$	0.45	1.16	2.56	0.01	0.01
15	$R\&Dr_{it-1}$	0.78	0.75	0.96	0.06	0.06
16	LAB_{it-1}	117,493,284	239,241,358	2.036	181,860	181,860
17	$GDPcap_{it-1}$	25,155	29,066	1.155	2,198	2,198
18	FDI_{it-1}	35,596,744,724	69,974,037,360	1.966	114,664,435	114,664,435
19	$BUSenv_{it-1}$	69.31	18.06	0.26	23.72	23.72

PTN_{it} is total patents; $INTRA_{it}$ is intra-regional collaborative papers; $EXTRA_{it}$ is interregional collaborative papers; $TRDr_{it}$ is ratio between trade and GDP; $EDUr_{it}$ is ratio of education spending to GDP; $R\&Dr_{it}$ is ratio of R&D spending to GDP; $ln LAB_{it}$ is total labour; $ln GDPcap_{it}$ is GDP per capita country; $ln FDI_{it}$ is FDI inflow; $ln BUSenv_{it}$ is ease doing business score; $ln INTRA_{it-1}$ is intra-regional collaborative papers lagged one-year; $ln EXTRA_{it-1}$ is interregional collaborative papers lagged one-year; $EDUr_{it-1}$ is ratio of education spending to GDP lagged one-year; $TRDr_{it-1}$ is ratio of trade to GDP lagged one-year; $R\&Dr_{it-1}$ is ratio of R&D spending to GDP lagged one-year; $ln LAB_{it-1}$ is total labour lagged one-year; $GDPcap_{it-1}$ is total value GDP per capita lagged one-year; FDI_{it-1} is FDI inflow lagged one-year; $BUSenv_{it-1}$ is ease doing business score lagged one-year.

Source: author

Among seven control variables, correlation between FDI and patents shows the strongest relation, while the least correlation occurs between GDP per capita and patents. FDI and GDP

per capita also present similar results when correlated with variable intra-regional collaboration. While correlation with extra-region collaboration, FDI demonstrates the smallest coefficient.

Table 6. 2 Correlation matrix between contemporaneous variables

	Variables	1	2	3	4	5	6	7	8	9	10
1	*ln*PTN$_{it}$	1									
2	*ln*INTRA$_{it}$	0.847	1								
3	*ln*EXTRA$_{it}$	0.934	0.957	1							
4	EDUr$_{it}$	0.395	0.391	0.957	1						
5	TRDr$_{it}$	0.544	0.350	0.391	0.514	1					
6	R&Dr$_{it}$	0.477	0.536	0.350	0.040	0.260	1				
7	*ln*LAB$_{it}$	0.751	0.567	0.536	0.267	0.155	-0.128	1			
8	*ln*GDPc$_{it}$	0.026	0.127	0.567	0.039	0.468	0.674	0.608	1		
9	*ln*FDI$_{it}$	0.869	0.854	0.127	0.234	0.297	0.514	0.660	0.014	1	
10	*ln*BUSenv$_{it}$	0.588	0.712	0.854	0.616	0.691	0.471	0.141	0.455	0.494	1

Source: author

Table 6. 3 Correlation matrix between lagged one-year variables

	Variables	1	2	3	4	5	6	7	8	9	10
1	*ln*PTN$_{it}$	1									
2	*ln*INTRA$_{it-1}$	0.853	1								
3	*ln*EXTRA$_{it-1}$	0.877	0.916	1							
4	EDUr$_{it-1}$	0.377	0.369	0.418	1						
5	TRDr$_{it-1}$	0.546	0.351	0.403	0.513	1					
6	R&Dr$_{it-1}$	0.436	0.542	0.538	0.041	0.263	1				
7	*ln*LAB$_{it-1}$	0.765	0.573	0.680	0.250	0.155	0.122	1			
8	*ln*GDPc$_{it-1}$	0.003	0.124	0.055	0.042	0.474	0.675	0.605	1		
9	*ln*FDI$_{it-1}$	0.860	0.836	0.869	0.205	0.296	0.515	0.661	0.014	1	
10	*ln*BUSenv$_{it-1}$	0.623	0.716	0.662	0.611	0.706	0.470	0.157	0.455	0.489	1

Source: author

The following correlation is between one-year-lagged variables (see Table 6.3) and demonstrates that correlation between the independent variables and dependent variables are not too much different as contemporaneous variables. Only GDP per capita shows a weaker correlation to patents.

From Tables 6.1, 6.2 and 6.3, several interesting insights can be derived. First, intra-regional collaboration and extra-regional collaboration are strongly correlated indicating both of them

are complementary for knowledge flows. Second, the collaboration rate is higher when number of labourers and FDI rate are higher. Third, the lagged one-year generally brings a slightly different of correlation between explanatory and control variables.

6.4 Model Specification

In order to measure the impact of knowledge flows through collaborative research on innovation, intra-regional collaboration along with control variables is first estimated, followed by interregional collaboration with control variables, and the last to be elaborated is intra-regional collaboration and interregional collaboration with control variables through contemporaneous panel data regression. Fixed effects (FE) have been introduced to address country-level unobserved heterogeneity. FE proposes all elements of unobserved heterogeneity that are constant for an origin country collaborator across all country partners and constant for a country partner across all origin countries collaborator (Shepherd, 2019). Kinds of literature reveal motivation adopting FE regarding GDP and economic activities (e.g trade and investment) which is sensitive to time (year), and multilateral resistance terms seem appropriate to FE criteria. This thesis includes country FE and year FE in contemporaneous variable and one-year lagged variables. Besides, FE applied in the one-year lagged variable to investigate how the effect of explanatory variables and control variables behaves in the lagged variables comparing to contemporaneous variables.

The model for fixed effects is proposed as follows:

$$\gamma ln\,\mathrm{PTN}_{it} = \beta_0 + \beta_1\, ln\,\mathrm{INTRA}_{it} + \beta_2\, ln\,\mathrm{EXTRA}_{it} + \beta_3\mathrm{TRDr}_{it} + \beta_4\mathrm{EDUr}_{it} + \beta_5\mathrm{R\&Dr}_{it} + \beta_6\, ln\,\mathrm{FDI}_{it} + \beta_7\, ln\,\mathrm{LAB}_{it} + \beta_8\, ln\,\mathrm{GDPc}_{it} + \beta_9\, ln\,\mathrm{BUSenv}_{it} + \mu_i + \mu_t + \varepsilon_{it}$$

Where $\gamma ln\,\mathrm{PTN}_{itt}$ is the total number of patents in country *i*; $\beta_1\, ln\,\mathrm{INTRA}_{it}$ is the total number of intra-regional co-authored papers for country *i;* $\beta_2\, ln\,\mathrm{EXTRA}_{it}$ is the total number of interregional co-authored papers for country *i*; $\beta_3\mathrm{TRDr}_{it}$ is the ratio of total trade value to total GDP country of *i*; $\beta_4\mathrm{EDUr}_{itt}$ is the ratio of total education spending to total GDP for country *i*; $\beta_5\mathrm{R\&Dr}_{it}$ is the ratio of total R&D spending to total GDP country for $i\beta_6\, ln\,\mathrm{FDI}_{it}$ is the total volume of FDI inflow for country *i*; $\beta_7 ln\mathrm{LAB}_{it}$ is total labour force of country *i*; $\beta_8 ln\mathrm{GDPcap}_{it}$ is total value of GDP per capita for country *i*; $\beta_9 ln\mathrm{BUSenv}_{it}$ is ease of doing business score as proxy of government policy supporting business environment of country *i*; μ_i is dummy for country fixed effect; μ_t is dummy for year fixed effect; and ε is error term. This model consists of nine countries with a time duration of 11 years.

Nevertheless, lagged one-year variables have been introduced into the model as part of overcoming partly the endogeneity problem. It is widely known that the application process for patents takes one year for an invention to be registered as a patent. Most of the patent offices require at least one year to assess an application and decide whether it should be granted a patent or rejected (Fornahl, Broekel and Boschma, 2011). This has been taken into consideration as the time lag between collaborative research and patent being a minimum of one year. A specification model with one-year lagged variables is proposed as follows:

$$\gamma ln\,\mathrm{PTN}_{it} = \beta_0 + \beta_1\, ln\,\mathrm{INTRA}_{it-1} + \beta_2\, ln\,\mathrm{EXTRA}_{it-1} + \beta_3\mathrm{TRDr}_{it-1} + \beta_4\mathrm{EDUr}_{it-1} + \beta_5\mathrm{R\&Dr}_{it-1} + \beta_6\, ln\,\mathrm{FDI}_{it-1} + \beta_7\, ln\,\mathrm{LAB}_{it-1} + \beta_8\, ln\,\mathrm{GDPc}_{it-1} + \beta_9\, ln\,\mathrm{BUSenv}_{it-1} + \mu_i + \mu_t + \varepsilon_{it}$$

6.5 Estimation Results

The whole set of estimation results of the contemporaneous panel data regression is displayed in Table 6.4, beginning with intra-regional collaboration (first column), interregional collaboration (second column), followed with elaborated intra-regional and interregional simultaneously into an integrated model (third column). Finally, year dummies and country dummies (*i*) have been added in model 4 to model 6.

Table 6. 4 Econometric outputs with contemporaneous variables (2006-2016)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
*ln*INTRA$_{it}$	0.086		0.082	0.459***		0.465**
	(0.098)		(0.136)	(0.168)		(0.193)
*ln*EXTRA$_{it}$		0.198*	0.261*		0.243	0.013
		(0.105)	(0.149)		(0.201)	(0.221)
TRDr$_{it}$	-0.465****	-0.507****	-0.486****	0.233**	0.333**	0.232*
	(0.096)	(0.088)	(0.095)	(0.126)	(0.126)	(0.129)
EDUr$_{it}$	0.005	-0.025	-0.033	0.175***	0.210***	0.177**
	(0.048)	(0.050)	(0.052)	(0.073)	(0.078)	(0.077)
R&Dr$_{it}$	1.471****	1.344****	1.308****	0.283	0.209	0.289
	(0.111)	(0.131)	(0.144)	(0.182)	(0.219)	(0.215)
*ln*FDI$_{it}$	-0.005	0.001	0.010	0.093**	0.112**	0.093**
	(0.053)	(0.051)	(0.053)	(0.045)	(0.046)	(0.046)
*ln*LAB$_{it}$	1.099****	0.993****	0.988****	2.484****	3.131****	2.461****
	(0.076)	(0.098)	(0.099)	(0.742)	(0.821)	(0.842)
*ln*GDPc$_{it}$	0.432***	0.360**	0.374***	-0.123	-0.544	-0.125
	(0.138)	(0.138)	(0.140)	(0.390)	(0.365)	(0.393)
*ln*BUSenv$_{it}$	0.588	0.421	0.524	0.530***	0.778***	0.528**
	(0.371)	(0.326)	(0.369)	(0.259)	(0.249)	(0.263)
Constant	-16.186****	-13.995****	-14.598****	31.101****	42.493****	30.870**
	(2.937)	(2.862)	(3.042)	(11.233)	(11.289)	(11.942)
R-Squared (%)	97.3	97.4	97.4	98.6	98.5	98.6
Adj.R-Squared (%)	96.2	96.2	96.2	99.4	97.3	97.4
Country FE	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes
No. Obsv	99	99	99	99	99	99

Robust standard errors are reported in parentheses.
**** p <0.001; *** p <0.01; ** p < 0.05; *p < 0.1

Source: Author

Intra-regional collaboration has been introduced within model 1 and model 3 to test the impact of knowledge flows within a region on innovation performance. These have a positive but not

statistically significant effect ($p < 0.1$). In the meantime, extra-regional collaboration as sources of knowledge beyond the region shows a positive and significant effect, as expected ($p < 0.1$), and can be seen in model 2 and model 3. These demonstrate only collaboration with countries outside a region gives an impact on generating innovation.

In the meantime, dummy country FE and dummy year FE have been elaborated into model 4 to model 6 and give different results compared to the estimations without country FE and year FE (model 1 to model 3). Intra-regional collaboration pinpoint positive and statistically significant (at $p<0.01$) from model 4 and model 6. The coefficient will slightly increase by 0.465 if knowledge flows of the intra-region combine simultaneously with extra-regional collaboration. On the other hand, interregional collaboration shows a positive effect as expected but is not statistically significant for both models (5 and 6). This situation implies that extra-regional collaboration does not bring significant effects in stimulating innovation activities even with a smaller coefficient than intra-regional collaboration.

Since the variance inflation factor (VIF) value of extra-regional collaboration is beyond 15 and also there is found a high correlation between extra-region and intra-regional collaboration (0.957 and 0.984), multicollinearity exists in the extra-region variable. Multicollinearity can contaminate model estimation. However, the coefficient and degree of significance of the intra-region demonstrated has not much changed when both estimated individually with control variables (model 1 and model 4) and simultaneously with extra-regional and control variables (model 3 and model 6). These can confirm that multicollinearity seems to not much affect the model.

Control variables are the other important conditions influencing innovation performance. Among seven control variables, only labour consistently demonstrates a positive effect and is significant across models. The effect of labour on innovation performance demonstrates the strongest effect, seen from the coefficient (2.461) and degree of confidence ($p < 0.01$). The number of labourers implies the importance of country size to generate innovation. The importance of human resource generating innovation is also supported by a positive and significant ratio of education spending to GDP through the last three models with fixed effects. Sufficient spending on education is future investment that has the benefit of improving human resource quality, particularly for the higher-level education worker who intensively undertakes R&D activities. These have emphasised the importance of human resource factors stimulating innovation activities. On the other hand, a capital intensive, represented by GDP per capita and R&D spending ratio to GDP, is insignificant and suggests that innovation performance is not influenced by GDP per capita. In addition, the effect of technological intensity is also insignificant. Nevertheless, it seems human capital is more dominant than capital intensive investment in influencing innovation performance in ASEAN plus China.

Furthermore, the effect of trade openness is a positive and significant factor as expected. Trade openness provides advantages for ASEAN member states (AMS) plus China for generating innovation by easing the transfer of knowledge and skills, widening the opportunity for labour migration, supporting availability of production inputs, and resulting in increasing the total factors for productivity. Similar positive and statistically effect can be observed for FDI, as expected. Capital inflow is followed by knowledge flows since knowledge is attached to capital and production factors. Besides international relations, a positive effect of the business environment on innovation reflecting government policies are conducive for the growth of

business. Patents are associated with industries where a supportive business environment is fundamentally required in order to promote certainty in doing business, particularly for administration and bureaucracy processes, business regulations and protection of IPR. A country with a high awareness of IPR protection can be an incentive for inventors to generate inventions and new technology.

Table 6.5 shows the results of one-year lagged variables. The effect of intra-regional collaboration is weaker through the one-year lagged variable fixed effects estimation than the contemporaneous variable fixed effects estimation. This can be seen through model 10 and model 12 that demonstrate smaller coefficients (0.125 and 0.382). Extra-region collaboration through one-year lagged estimations show not significant in all model estimations (model 7 - model 12). Therefore, the results suggest one-year lagged is suitable to estimate the impact of knowledge flows on innovation performance.

In the meantime, the effect of control variables on innovation do not change much through one-year lagged variables estimation. There are five out of seven control variables are positive and significant affecting innovation. GDP per capita demonstrate a robust positive effect on generating knowledge. These can confirm that labour, the education spending ratio and trade are the most stable control variables through the contemporaneous variable and lagged one-year variable estimations.

Table 6. 5 Econometric outputs with one-year lagged variables and FE (2006-2016)

	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
ln $INTRA_{it-1}$	0.029		0.081	0.125***		0.382**
	(0.134)		(0.187)	(0.387)		(0.456)
ln $EXTRA_{it-1}$		0.096	0.155		1.056	1.203
		(0.139)	(0.951)		(0.345)	(0.377)
$TRDr_{it-1}$	-0.422***	-0.453****	-0.430***	0.190*	0.307*	0.334*
	(0.127)	(0.116)	(0.128)	(0.211)	(0.201)	(0.203)
$EDUr_{it-1}$	-0.145**	-0.159**	-0.168**	0.112*	0.275**	0.236**
	(0.061)	(0.064)	(0.068)	(0.134)	(0.125)	(0.132)
$R\&Dr_{it-1}$	1.159****	1.092****	1.062****	0.329	0.172	0.189
	(0.148)	(0.177)	(0.191)	(0.322)	(0.341)	(0.342)
ln FDI_{it-1}	0.046	0.048	0.055	0.029	0.061	0.046
	(0.068)	(0.067)	(0.069)	(0.081)	(0.075)	(0.076)
ln LAB_{it-1}	0.988****	0.928****	0.925****	0.590**	1.307*	1.828***
	(0.109)	(0.127)	(0.069)	(0.146)	(0.147)	(0.156)
$GDPc_{it-1}$	0.220	0.175	0.190	3.211****	3.920****	3.446****
	(0.185)	(0.185)	(0.189)	(0.889)	(0.674)	(0.834)
$BUSenv_{it-1}$	1.912****	0.1773****	1.885****	1.242**	1.179***	1.398***
	(0.510)	(0.440)	(0.512)	(0.485)	(0.396)	(0.456)
Constant	-20.189***	-18.703***	-19.367***	34.203**	31.541****	20.628***
	(3.892)	(3.739)	(4.035)	(13.275)	(12.014)	(12.994)
R-squared (%)	97.2	97.2	97.2	98.7	98.9	98.9
Adj.R-Squared (%)	96.9	96.3	96.9	97.3	98.5	98.5
Year FE	No	No	No	Yes	Yes	Yes
Country FE	No	No	No	Yes	Yes	Yes
No. Obsv	90	90	90	90	90	90

Robust standard errors are reported in parentheses.
**** p<0.001; *** p<0.01; ** p < 0.05; *p < 0.1
Source: Author

The estimation one-year lagged has demonstrated robust evidence on the impact of intra-region and some control variables in generating innovation. At the firm's level, one-year lagged estimation has generally employed to investigate the effect of R&D spending on patent productivity since the impact of R&D expenditures can be seen at least in one year (Vancauteren *et al.*, 2017). Also, this study has estimated two-years lagged variables (model 21), and three-years lagged variables (model 22) presented low sensitivity (**see appendix III**). There only two control variables out of seven are significant, while intra-region and extra-region are not significant. Therefore, one-year lagged variables estimation seems appropriate to investigate the effect of collaboration on innovation generation.

To observe ASEAN countries' common characteristic through reducing the effect of prominent countries' domination in ASEAN and China's IRC network structure, this study has estimated the following models by excluding China and Singapore from the observations (Table 6.6). These estimations give more potent effects than estimation in Table 6.4 (contemporaneous variables) and Table 6.5 (one-year lagged variables). Omitting China and Singapore from observation has led to FDI and business environment variables cannot explain the effect on generating innovation in contemporaneous FE (model 14) since China and Singapore are the highest countries receiving FDI in the region. Estimation results in table 6.6 found intra-region, trade, labour, and business environment are steady significant regarding results in table 6.4 and table 6.5.

Table 6. 6 Econometric outputs of contemporaneous variables and lagged variables without China and Singapore (2006-2016)

	Model 13	Model 14		Model 15	Model 16
lnINTRA$_{it}$	0.171	0.467**	$\ln INTRA_{it-1}$	0.843****	0.885**
	(0.310)	(0.398)		(0.287)	(4.824)
lnEXTRA$_{it}$	0.242	0.131	$\ln EXTRA_{it-1}$	0.720	0.767
	(0.301)	(0.531)		(0.260)	(4.897)
TRDr$_{it}$	-0.422**	0.814***	$TRDr_{it-1}$	0.308**	3.831*
	(0.164)	(0.095)		(0.140)	(2.272)
EDUr$_{it}$	0.051	0.168	$EDUr_{it-1}$	0.153*	2.278*
	(0.052)	(0.171)		(0.085)	(0.158)
R&Dr$_{it}$	0.997**	0.599	$R\&Dr_{it-1}$	1.213***	1.813
	(0.481)	(0.633)		(0.399)	(0.569)
lnFDI$_{it}$	0.048	0.044	$\ln FDI_{it-1}$	0.371	2.944
	(0.102)	(0.094)		(0.086)	(0.877)
lnLAB$_{it}$	1.147****	0.954***	$\ln LAB_{it-1}$	1.189****	3.582*
	(0.076)	(0.219)		(0.165)	(2.066)
lnGDPc$_{it}$	0.525**	2.457**	$GDPc_{it-1}$	0.449**	4.793***
	(0.252)	(1.137)		(0.218)	(1.477)
lnBUSenv$_{it}$	0.460	0.488	$BUSenv_{it-1}$	1.533***	1.544***
	(0.639)	(0.566)		(0.556)	(5.271)
Constant	-20.624****	-24.325****	Constant	22.538****	17.580
	(4.576)	(2.444)		(4.452)	(2.783)
R-Squared (%)	96.5	98.6	R-squared (%)	95.8	98.2
Adj.R-Squared (%)	96.0	98.1	Adj.R-Squared (%)	95.1	97.3
Country FE	No	Yes	Year FE	No	Yes
Year FE	No	Yes	Country FE	No	Yes
No. Obsv	99	99	No. Obsv	70	70

Robust standard errors are reported in parentheses.
**** p <0.001; *** p <0.01; ** p < 0.05; *p < 0.1

Source: Author

However, countries with higher investments tend to produce more patents by acquiring knowledge from intra-region collaborations and extra-region collaborations. This research has elaborated interaction effects into the model estimations[10] (see table 6.7). To estimate the interaction effect, I employed variable of FDI*INTRA and FDI*EXTRA.

[10] Interaction effect has been estimated in several models by elaborating several variables cross-effect like: FDI*INTRA, FDI*EXTRA, GDP*INTRA, GDP*EXTRA, R&D*INTRA, R&D*EXTRA. Only FDI*INTRA and FDI*EXTRA have the most consistent results in four different model estimations (Model 17-Model 20).

Table 6. 7 Econometric outputs of interaction effects of contemporaneous variables and lagged variables (2006-2016)

	Model 17	Model 18		Model 19	Model 20
lnINTRA$_{it}$	36.860**	31.065*	ln INTRA$_{it-1}$	35.968*	18.687*
	(17.738)	(20.423)		(14.209)	(11.525)
lnEXTRA$_{it}$	18.426	5.572	ln EXTRA$_{it-1}$	17.569	14.531
	(18.014)	(13.799)		(14.584)	(11.122)
TRDr$_{it}$	-0.453**	0.802****	$TRDr_{it-1}$	-0.428***	0.336
	(0.141)	(0.224)		(0.129)	(0.217)
EDUr$_{it}$	0.013	0.163	$EDUr_{it-1}$	0.168**	0.234*
	(0.077)	(0.133)		(0.194)	(0.135)
R&Dr$_{it}$	1.206****	0.163***	$R\&Dr_{it-1}$	1.063****	0.186
	(0.212)	(0.370)		(0.194)	(0.348)
lnFDI$_{it}$	18.467	6.535*	ln FDI_{it-1}	3.974	3.299*
	(2.144)	(16.723)		(1.445)	(12.468)
lnLAB$_{it}$	1.109****	0.789**	ln LAB_{it-1}	0.919****	1.879
	(0.150)	(1.440)		(0.131)	(1.604)
lnGDPc$_{it}$	0.421**	2.518*	$GDPc_{it-1}$	0.179*	3.417****
	(0.209)	(0.684)		(0.194)	(0.864)
lnBUSenv$_{it}$	0.931*	0.421*	$BUSenv_{it-1}$	1.918***	1.408***
	(0.549)	(0.467)		(0.522)	(0.479)
lnFDIINTRA$_{it}$	27.126**	12.175*	ln FDIINTRA$_{it-1}$	36.059*	19.081*
	(17.749)	(13.141)		(14.213)	(11.531)
lnFDIEXTRA$_{it}$	18.624	5.685	ln FDIEXTRA$_{it-1}$	17.585	15.741
	(17.987)	(13.850)		(14.585)	(11.127)
Constant	-20.102****	-33.065**	Constant	22.538****	19.818*
	(4.576)	(20.423)		(4.452)	(2.783)
R-Squared (%)	96.5	97.6	R-squared (%)	97.7	98.9
Adj.R-Squared (%)	96.1	96.4	Adj.R-Squared (%)	96.9	98.4
Country FE	No	Yes	Year FE	No	Yes
Year FE	No	Yes	Country FE	No	Yes
No. Obsv	99	99	No. Obsv	90	90

Robust standard errors are reported in parentheses.
**** p <0.001; *** p <0.01; ** p < 0.05; *p < 0.1
*ln*FDIINTRA$_{it}$ is variable cross-effect FDI*INTRA; *ln*FDIEXTRA$_{it}$ is variable cross-effect FDI*EXTRA; *ln* FDIINTRA$_{it-1}$is variable cross-effect FDI*INTRA lagged one-year, *ln* FDIEXTRA$_{it-1}$ is variable cross effect FDI*INTRA lagged one-year.

Source: Author

Variable of cross-effect between FDI and intra-region collaboration demonstrates stability in estimations of contemporaneous variables and one-year lagged variables. The cross-effect variable is incorporated with intra-region collaboration (as explanatory variables) and GDP per

capita and business environment (as control variables) across the models. Estimation results table 6.7 are consistent with the results in table 6.4 and 6.5.

6.6 Concluding Discussion

The development of huge resources of academic knowledge in Global North (GN) countries led to the GN being advanced in producing innovation compared to other countries. The literature suggests innovation is the foremost instrument transforming socio-economic elements and accelerating development in many countries. The effect of innovation is obviously seen in GN countries like the United Kingdom, France and Germany, where their income economies have increased up two thirds, while the United States shows the highest increase at close to 80% (Wattanapruttipaisan, 2004). The success story of transforming academic knowledge into innovation has inspired Global South (GS) countries to pursue similar strategies. Disparity in academic capacity has produced widening technological divergence between GN countries and GS countries which encourages GS countries to acquire international knowledge, particularly from GN countries, to be combined with local knowledge.

Many low-income economy countries count external knowledge as the main source of innovation which diffuses through five main channels: international trade, FDI, collaborative research, migration and licensing (Fagerberg, Srholec and Verspagen, 2010; Cappelli and Montobbio, 2014). Since data for migration and licensing in low-income countries are limited, empirical studies mostly focused on the first three factors as the main instruments of knowledge flows.

The effect of knowledge flows on innovation through collaborative research is only seen from intra-regional collaboration which demonstrates stronger impacts than interregional collaboration. There some rationales behind this. *First*, the significance of intra-regional collaboration reflects that geographical proximity is a crucial element in regard to diffusing external knowledge and transforming knowledge into innovation. Generating innovation involves an intensive research activity within the long term and continuous process which is undertaken by institutions which are capable academically and practically. In addition, the process to create innovation is pricey, complex, dicey and interdependent between elements which require intense coordination and connectivity. It means distance is a matter determining an intense coordination and better connectivity between institutions which undertake research activities, for example at laboratories and designed plants. In addition, geographical closeness is one of the fundamental factors allowing knowledge to diffuse smoothly due to the possibility of sharing equipment and resources as research inputs and human resource mobility. The findings from this chapter are relevant to the previous chapters (5 and 2) in that geographical factors not only determine international collaboration but also influence knowledge flows into the region and combination with existing knowledge as the part of the process of creating innovation. Moreover, this result is similar with previous studies on how geographical proximity affects knowledge diffusion in generating innovation in other countries (Moodyson, Coenen and Asheim, 2008; Mattes, 2012; Zanello *et al.*, 2016b).

Second, ASEAN has implemented several policies and instruments that are conducive to growing innovation within the region. Following the formation of ASEAN, the Committee of Science, Technology and Innovation (COSTI) was established internally by the ASEAN secretariat to facilitate AMS activity in the Science Technology and Innovation (STI) sector.

Collaboration was manifested through joint projects, workshops and initiatives. Regional innovation has recently been formulated into the ASEAN Plan of Action and Science, Technology and Innovation (APASTI) 2016–2025. This has been supported by the ASEAN Working Group on Intellectual Property Cooperation (AWGIPC) altogether with ASEAN expert groups on patents and on trademarks. Moreover, the presence of the World Intellectual Property Organization (WIPO) office in Singapore since 2005 has facilitated ASEAN country members advocating and registering their inventions through patents, trademarks and international design systems (WIPO, 2019b). In addition, WIPO collaborates with the ASEAN secretariat in continuously promoting specific programmes to protect ideas and inventions from ASEAN member states (AMS) that are economically valuable. Some examples of programmes that have been undertaken are technical training for human resources, workshops and seminars for management quality, bridging cooperation between EU-funded and ASEAN Intellectual Property Rights (ARISE+)[11] Intellectual Property Rights (IPR)[12] programmes, simplifying the procedure to register IPR in the region to cut administrative procedure and processing time, integrated IPR regulation and systems in the region, tailor-made empowerment schemes for members with the least innovation (Cambodia, Laos, Myanmar) and development of the

[11] ASEAN Regional Integration Support from the European Union (ARISE) was established in 2013 as part of EU technical assistance to ASEAN to accelerate regional integration due to close relationships between ASEAN and the EU since 1977. This programme cost € 22 million and was carried out for capacity empowerment, implementing the single market and institution building for the ASEAN secretariat. A successful implementation of ARISE has promoted ARISE+ (plus) as an extension of support from the EU for ASEAN integration. This programme started in 2016 to 2025 with four main areas: efficient bureaucracy, accountability and transparency, reporting and evaluation of economic integration, and standards and procedures unification for cross-border flows https://ariseplus.asean.org/about/.

[12] ARISE Plus Intellectual Property Rights (ARISE+ IPR) is a following programme as a part from ARISE plus the primary objective to improve the Intellectual Property (IP) system in ASEAN (https://euipoeuf.eu/en/ariseplusipr). This was started with the EU-ASEAN Project on the Protection of Intellectual Property Rights (ECAP) to foster ASEAN integration and to improve IP region system in respect to global standards (http://ecap3.org/about/ecap-iii-phase-ii). Strengthening the IP system and procedure is expected to bring a conducive environment to grow innovation and impact on increasing productivities in the region for the medium and long term.

ASEAN Intellectual Property Academy (IPA). In order to encourage collaborative research for innovation within the region, the ARISE+ IPR programme provided specific funds (roughly €5.5 million) undertaken by ASEAN to foster Intellectual Property (IP) cooperation between AMS, parallel with ASEAN economic integration. In the other words, joint collaboration in research and innovation activities is expected to strengthen economic integration within the region.

Apart from the WIPO office and ARISE+, there are various initiatives working together with the ASEAN secretariat to enhance knowledge exchange and collaboration on projects producing innovation. The ASEAN IPA founded on 1st December 1996 is a home for industries and private entities to share their knowledge, and undertake innovative projects and studies (ASEANIPA, 2017). While at the academic level, ASEAN with support from the German Federal Ministry for Economic Cooperation and Development (BMZ) are creating pilot projects between universities and industries in collaboration for innovation (Bartels, 2018). Moreover, Singapore was initiated into ASEAN innovation networks with a focus area in digital economy to foster knowledge exchange, expertise and open collaboration to generate innovation. Furthermore, the ASEAN secretariat has been seeking support from ASEAN plus three (China, South Korea, and Japan) to accelerate ASEAN integration through resilience and STI lately through ASEAN-China, ASEAN-Republic of Korea Cooperation Fund, and ASEAN-Japan under the Free and Open Indo-Pacific Strategy (FOIP). However, various policies implemented by the ASEAN secretariat are potentially beneficial in easing collaborative research between AMS and stimulating the members in undertaking further innovation projects. All of these strategies may trigger knowledge flows through intra-regional collaboration and may be more robust to drive innovation activities in the region.

Third, as has been discussed in chapter (4), although interregional collaboration is much greater than intra-regional collaboration, the effect on generating innovation in the region is not statistically significant. This finding is similar to the previous study about the efficiency of international collaboration between global cities showing that collaborative research with cities in Asia is less efficient. This has been demonstrated through the high the volume of co-authored papers that have low citations, which implies collaborative research gives a small impact on creating new knowledge in Asian cities (Csomos and Lengyel, 2019). Although collaborative research may stimulate the increase in the volume of scholarly outputs, however, external knowledge beyond region seems barely diffused and elaborated with existing knowledge in ASEAN and China, which is difficulty seen from effect on innovation generation.

Fourth, this chapter may address an issue about unequal advantages generated from collaborative research between GN countries and GS countries by giving evidence that knowledge flows from GN countries (interregional collaboration) do not statistically give an impact on innovation in ASEAN and China as part of GS countries. In the meantime, as innovation is a result from an interactive cooperation between three basic dimensions (knowledge, geography and economy), the finding implies mutual collaboration between GN countries and GS countries seems does not exist. In the other words, GN countries possibly receive much greater gains from the collaboration between them than GS countries due to the unbalanced academic capacity and technological intensity between them.

In the meantime, other factors have influenced innovation creation along with knowledge flows. Knowledge flows and research collaboration studies in the literatures indicate that FDI and

trade are the most measurable instruments in regard to sources of innovation. FDI allows knowledge spill over from foreign companies to local companies. China and Singapore have been successful in managing FDI to upgrade their technological capacity which is fundamentally needed to grow internal innovation. Increasing technological capacity from FDI has been the ladder for them to reap innovation by combining with other inputs. Furthermore, trade openness facilitates the acquisition of external knowledge and inputs from international sources, for example: machinery, foreign technology and materials that are essentially required to create innovation. Trade openness is conducive to produce imitation of foreign technologies as the basic level to produce innovation. On the other hand, inadequate IP creation in most of AMS lead them to highly depend on imported technologies; Singapore, Malaysia, Indonesia, Thailand and Philippines are the biggest countries contributing to imported IPRs in ASEAN (Ambashi *et al.*, 2018). However, a successful diffusion of external knowledge using channels of FDI and trade are influenced by national policies that are supportive both for business and for conducting R&D. In other words, the business environment index represented by government policies can give certainty in business for the private sector, particularly in efficient administration processes, law enforcement and coordination between government bodies which is supportive for innovation to grow.

ASEAN has been growing as a region of emerging economies which is labour intensive and is one of the main drivers. The ASEAN secretariat undertakes labour empowerment for information and communication technologies (ICT) and promotes skills development in respect of the regional integration process. In the meantime, awareness of the importance of human resources has been rising in most of the AMS which is represented by the increasing ratio of

education spending to GDP in the last 11 years. A combination between a large labour force and investment in the education sector is advantageous to undertake innovation activities.

As has been explained in previous chapters (4 and 5), ASEAN has grown as a region from heterogeneous countries with diverse backgrounds. Currently, ASEAN is facing a challenge with income disparity between AMS. The most obvious income gap can be seen between the wealthiest countries (Singapore and Brunei Darussalam) and the countries with least income economies (Cambodia, Myanmar, Laos) that can be up to 49 times different. This may cause the effect that GDP per capita is statistically not significant. Also, average technological intensity in ASEAN is relatively low (less than 0.6% ratio to GDP) which is not significant to impact on growing innovation, in comparison with technological intensity in GN countries with advanced innovation and academic knowledge, ranging 2%–4%. For example, in Indonesia, one of the AMS, the technological intensity has not much changed over 11 years (roughly at 0.8%). In addition, R&D spending was getting worse in the private sector which had decreased more than 50% (Kuncoro, 2012). This reflects there was a shifting priority in industry from technology intensive to the primary sector (mining, agriculture, mineral) industries. This similarly has been experienced by other AMS such as Philippines, Vietnam, Cambodia, Laos, Myanmar (Ambashi *et al.*, 2018). On the other hand, the effect of booming prices in the primary sector (oil, mineral and gas) since the last two decades (from the beginning of 21st century) has impacted on most of the R&D spending invested in this sector, which is popularly known as 'Dutch disease'. 'Dutch disease' brings negative effects on the learning process to generate innovation since R&D investment has been allocated on low innovation intensive sector. As a result, industries generally tend to import technologies since IP creation within the nation is insufficient.

This study has demonstrated another perspective for interlinking between knowledge flows and innovation in GS countries. *First*, collaborative research through co-authored papers bring effects on generating innovation with respect to geographical closeness. This gives a new insight that knowledge flows are not only dominated by trade, FDI, migration, and collaborative patents which have been comprehensively studied as knowledge channels both in GS countries and GN countries. *Second*, the relation between knowledge flows and innovation in GS countries has a different pattern with GN countries, where the various characters of the members in the region have influenced different results. *Third*, high dependency on GN countries as the source of external knowledge has not brought equal advantages for GS countries as collaborators. This point can be one of the considerations to redesign collaborative research schemes between GN countries and GS countries to achieve mutual collaboration.

CHAPTER VII
CONCLUSION

7.1. Introduction

In spite of the existence of abundant literature associated with knowledge flows, collaborative research and knowledge production (see chapter 2), the current knowledge is mostly based on studies of countries from the GN due to their outstanding performance in producing academic knowledge, their research quality and high volume of publications. It has potentially impacted on efforts to promote mutual and sustainable collaboration between the GN and GS as understanding of GS countries is limited in knowledge flow literatures. It can be said that the implementation of IRC between the GN and GS will remain influenced by nuances of 'scientific colonialism' (Connell *et al.*, 2017; Owusu-Nimo and Boshoff, 2017) and a 'Donor-Recipient relationship' (Johnson and Wilson, 2006) due to insufficient academic documentation of GS countries as an expression and evidence of how collaboration should be undertaken mutually.

This research aims to understand knowledge production through IRC in ASEAN and China (as representative of countries from the GS over 11 years (2006–2016). This has been manifested in three particular dimensions: 1) an identification of the development of the IRC network structure for both intra-region and extra-region collaboration; 2) an examination of the determinant factors influencing the likelihood of undertaking IRC; and 3) an estimation of the impact of knowledge flows in generating innovation. Three different methods (SNA, Gravity Model NB panel regression and lagged panel regression) have been employed to analyse three different dimensions of knowledge production. Therefore, the findings from three empirical chapters emphasis several significant issues for theory and methodology.

Firstly, the contribution of this study expands the current perspective about knowledge flows by delivering views of countries from GS. Central position in the collaborative research network structure is closely related to an outstanding performance in academic publication and ability to maintain number of ties with collaborative country partners as pair in IRC. Geographical proximity remains a fundamental factor in knowledge production across the world and is also experienced by countries in the GS. This has extended the conventional paradigm about the importance of geographical factors in knowledge flow literature; however, recently it has been seen as less important (Malmberg and Maskell, 2006; Hansen, 2015) due to advances in development and innovation in ICT sectors in what is popularly called 'The Death of Distance' (Frenken *et al.*, 2009; Nijkamp, 2017). Distance is not only determining the likelihood of undertaking IRC but also influencing knowledge diffusion in respect to stimulating innovation generation. The determinant factors of IRC in GS countries present different patterns than those generally occurring in GN countries. Country characteristics in the GS may differ from the GN countries which has affected the findings. Colonial ties remain in existence and have been substantial for GS countries in developing and maintaining cooperation with GN countries, although the existence of colonial ties presumes triggering unequal collaboration between them. Organisational similarity may not affect IRC because of a weak capability of the intergovernmental organisation in bridging different interests between the members. Language similarity does not work in determining propensity to collaborate when applied in the broader scope of analysis. The size of countries is not always associated with a tendency to conduct IRC and it has broadly been viewed negatively in determining IRC (Melin and Persson, 1996, 1998; Melin, 1999).

Secondly, delivering an empirical evidence of unequal collaboration of GN countries and GS countries through quantitative analysis. An indication of unequal collaboration between GN countries and GS countries which was initially discussed in the qualitative approach (Gaillard, 1994; Jentsch and Pilley, 2003; Johnson and Wilson, 2006; Bradley, 2014; Chetwood, Ladep and Taylor-Robinson, 2015; Biraimah, 2016) has been proven through the findings of this thesis. This study reveals that a high dependency on knowledge flows from GN countries has not brought a significant advantage for countries in the GS. It suggests mutual collaboration between GN countries and GS countries cannot be seen through IRC. In the broader context, this finding also provides evidence that co-authored publications can be acknowledged as an instrument to identify knowledge flows which are popularly examined via FDI and trade as the prominent channels of knowledge diffusion (Fagerberg, Srholec and Verspagen, 2010; Cappelli and Montobbio, 2014). In the meantime, this study has also confirmed FDI and trade are more dominant as channels for knowledge flow than collaborative research in GS countries. This thesis emphasises previous studies that FDI and trade are primary instruments in acquiring external knowledge, particularly for countries that have limited capacity to generate knowledge production (Williams and Balaz, 2008).

Thirdly, presenting the motivations undertaking IRC that has elaborated as variables of in the model estimation. The thesis has enhanced existing literatures of collaborative research and knowledge production by examining statistically the catalysts of IRC in GS countries. Academic performance (publications) and international incentives (e.g., research funds, sharing of research facilities and materials) are the most robust motivations. In the meantime, predominant research studies in the literature that identify the underlying factors to pursue IRC

have been assessed generally in a qualitative approach (Katz and Hicks, 1997; Katz and Martin, 1997; Georghiou, 1998; Schubert and Glanzel, 2006; Crossley, 2014).

This research has successfully delivered the main contributions emphasised above, and this further section will summarise the findings of the study in order to address the research questions. It will begin by presenting the structure of knowledge production during the last 11 years (2006–2016), continuing with identification of the determinant factors for IRC and discussion of the effect of knowledge flows on stimulating innovation. The following section will present the research implications from the findings. The research limitations during research project implementation and potential future research will be outlined in the final section in this chapter.

7.2. Main Findings of the Thesis

7.2.1 The Structure of Collaborative Research Network in ASEAN and China

The structure of the collaborative research network generally remained the same over 11 years (2006–2016) particularly for the top hierarchy and middle hierarchy. China and Singapore have been the central countries in the network structure for both intra-region (within region) and extra-region (between ASEAN and China with non-ASEAN/China countries) which was implied from the WDC score. There is a tendency that the performance of IRC is related to publication performance since China and Singapore are the most productive countries in publishing papers. Otherwise, countries like Cambodia, Myanmar and Laos located in the periphery of the network structure have encountered several limitations such as lack of human resources, low-income economies and low academic performance, both in institutions and in publications. Besides the hierarchical structure, the WDC score also reflected the high

dependency of ASEAN and China on GN countries as sources of knowledge flows which were accounted as ten times greater than knowledge sourced within the region. Moreover, this dependency is emphasised through the low diversity score of countries with positions in the centre and middle of the network structure. It implies the majority of collaboration is undertaken with prominent countries which are recognised as GN countries. IRC with prominent countries (extra-region collaboration) tends to be stronger over the time. In the meantime, publication performance seems in line with the tendency to reside within same community. Moreover, other elements like similarities in culture, language, historical ties, and institutional interest in intergovernmental organisations indicate influence in the community structure development.

7.2.2 Determinant Factors Influencing IRC in ASEAN and China: Evidence from a Panel Gravity Model

In regard to country characteristics, only publications and GDP per capita statistically influence IRC. The volume of publications is identified as push and pull factors in collaboration. Countries with high performance in knowledge production will be more attractive as potential collaborator partners since high performance in publications generally reflects a high quality of institutions, knowledge and research. In contrast, countries with low performance in publication are encouraged to acquire external knowledge due to their low capacity in producing knowledge. GDP per capita is associated with research budget sufficiency. Besides acquiring external knowledge, IRC is perceived by researchers in GS countries as an opportunity to seek external funding, facilities and material to support their activities as they have been confronted with insufficient capacity of research and development. On the other side, researchers located in high-income countries tend to be reluctant to pursue external incentives since they have been facilitated with adequate incentives within the country. In the meantime, the size of population

does not always represent the number of researchers who are capable in knowledge production. This has produced the effect that the size of the population is not significant in determining IRC as IRC is essentially related to academic elements.

The effect of four different determinant factors related to proximity demonstrated dissimilar results. Geographical distance reduced the likelihood of undertaking IRC because of the cost and time involved in travelling abroad and effort needed to build international connectivity due to insufficient infrastructure development in ICT and transportation sectors in ASEAN countries. The existence of colonial ties between ASEAN countries with the mother colony country in the GN is significant in influencing the probability of conducting IRC. This result confirms the findings of the previous empirical chapter (4); historical ties have constructed a closer relationship between countries which is implied in the community structure. This may have triggered the dependency of GS countries on GN countries and unequal contributions in knowledge production that have been discussed qualitatively in many studies in the literature. Furthermore, language proximity does not work in promoting IRC activity in ASEAN and China; this may be caused by diverse language backgrounds among AMS and China. Organisational proximity reflected through participation as an active member in the APT regional framework cannot have fostered collaborative research activity. The various country backgrounds (economy and politics) of the members, the late regional integration process of ASEAN and institutional issues have potentially affected the APT performance in facilitating IRC. Moreover, international trade has facilitated the pursuit of IRC. In order to expand the international market, some MNC facilitate collaboration between international universities with local universities to grow local innovation. In addition, a collaboration sometimes demands imported machinery and raw materials to support research activities. Nonetheless, the findings

suggest two fundamental reflections. *First*, the size of countries does not always correlate with a country's probability to engage in IRC activities. *Second*, due to GS countries' characteristics differing from GN countries, the effect of determinant factors of IRC exhibits dissimilar from the general pattern in GN countries.

7.2.3 The Impact of Knowledge Flows on Innovation Generation in ASEAN and China

The effect of knowledge flows is only displayed through intra-regional collaboration which indicates the role of geographical factors have been fundamental in knowledge diffusion. Besides geographical factors, the presence of intergovernmental organisations helps to facilitate cooperation between members that seems conducive in stimulating innovation activities within the region. Since the volume of extra-regional collaboration is much greater than intra-regional collaboration (as has been discussed in chapter 4), unfortunately it does not bring significant effects on innovation generation. This indicates that the knowledge from GN countries to GS countries has not diffused optimally. In other words, new knowledge is poorly produced in GS countries via collaboration with countries in the GN. This finding responded to an indication of unequal collaboration between GN and GS (as described in chapter 2). Also, this thesis has also incorporated with a previous study about how the low efficiency of IRC in big cities in East Asia due to the high volume of collaboration but a small volume of citations (Csomos and Lengyel, 2019).

The effect of control variables on innovation generation differs. FDI can be utilised to upgrade internal technological capacity which is advantageous to generate innovation. In respect to low performance in producing IPR in most of the AMS, trade openness has been beneficial in

facilitating knowledge diffusion through imported technologies. Success in employing these two channels for knowledge diffusion is supported by national policies to create a conducive business environment, since innovation activities are associated with the productive sector. In the meantime, ASEAN and China are home for abundant human resources. A combination of large labour force and government support for improving education has resulted in a positive effect, stimulating innovation creation. Apart from the strength of ASEAN, this region has been facing income disparity between AMS which led to the effect that GDP per capita is not significant. In addition, the effect of technological intensity cannot be seen in stimulating innovation generation due to inadequate budget allocation for R&D activities that has been experienced by the majority of AMS. This has been exacerbated by allocated R&D investment in sector with low innovative intensive, like primary sector as the impact of the 'oil boom price' at the beginning of the 21st century. Some particular characteristics of ASEAN countries and China have been presumed to form a different pattern of effects on the control variables on innovation, compared to previous studies conducted in GN countries.

However, this chapter has been correlated to the findings from previous chapters (4 and 5). Unequal collaboration between GN countries and GS countries does exist as a result of asymmetric capacity in knowledge production and the presence of colonial ties leading to high dependency of GS countries on GN countries.

7.3. Research Implications

Across the world, geographical factors have been prominent factors inhibiting the likelihood to undertake IRC and also knowledge diffusion which is crucial in stimulating innovation activities. In order to strengthen international connectivity to ease IRC activities, further policy

actions need to be undertaken, particularly by accelerating the ICT infrastructure development in most AMS and the process of ASEAN integration. Accelerating regional integration in ASEAN will be beneficial in fostering intra-regional collaboration that may lessen the dependency on GN countries, as can be seen from regional policies and several cooperative projects in the intra-region that have been conducive for generating innovation within the region. This can be done by diminishing the gap between AMS in various dimensions such as income economies, human resources, the quality of academic institutions and education, infrastructure development and unification of bureaucratic processes for migration, trade, and capital flows.

This thesis suggests a high performance in collaborative research is not always associated with greater knowledge inflows. Therefore, this can be a turning point to revisit the current schemes of IRC between GN countries and GS countries in order to promote mutual collaboration between them. Simultaneously, leveraging country capacity can be undertaken by providing sufficient budget allocation for R&D activities which is expected to contribute to incentives for the researcher.

7.4. Research Limitations and Agenda for Future Research

This study has presented a notable contribution to the understanding of knowledge production in GS countries, particularly from ASEAN and China. It provides relational elements among the structure, determinant factors and the effect on innovation. In addition to several contributions, this thesis displays limitations that can be considered in future studies to fill the gaps.

Since this study employs quantitative analysis, the availability of and access to secondary data have been the main issues regarding the data collection process. For instance, retrieving metadata from Scopus is restricted to a maximum of 5,000 papers per year per country which, in total, resulted in 605,000 papers. In the meantime, with a duration of 11 years (2006–2016) and 11 countries as the research sample, this study requires approximately 4 million papers. This has been anticipated through imported data from the SciVal website with particular selection tools. Unfortunately, SciVal does not provide the metadata of the papers. As a result, citation analysis from co-authored papers cannot be conducted to measure the productivity. On the other hand, this project was confronted with budget limitations that prevented selection of a different data source which would give broader access to metadata. Furthermore, undertaking research in GS countries is challenging, particularly with poor data documentation and data openness. As a result, two countries (Myanmar and Cambodia) cannot be elaborated as the sample in the estimation of the effect of knowledge flows on innovation generation (chapter 3).

However, with some limitations, this study has been an initial stage to scrutinise the characteristics of knowledge production in GS countries. This may be manifested through further research as the future agenda. By employing different sources of data, investigating knowledge production in GS may be undertaken at meso level (cities or sub-national) because the most reputable universities or research institutions in Southeast Asia are located in the main (large) cities. The analysis can be combined with an exercising category of four main research subjects (Social Sciences, Health Sciences, Physical Sciences, Life Sciences). This may help to identify the subject areas in which GS countries are independent from GN countries. Finally, in keeping with the spirit to promote mutual collaboration, it seems relevant to follow up the findings of this thesis.

APPEENDIX I: ESTIMATION RESULTS OF POISSON REGRESSION WITH FE,2006-2016

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
lnPOP$_{it}$	-0.02			0.02	0.02	0.02	0.02	-0.01	0.01
	(0.04)			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
lnPOP$_{jt}$	-0.02			-0.02	0.02	0.02	0.05	-0.79	0.02
	(0.59)			(0.59)	(0.59)	(0.59)	(0.59)	(0.65)	(0.03)
lnGDPC$_{it}$		-0.37**						-0.33**	-0.01
		(0.16)						(0.17)	(0.03)
lnGDPC$_{jt}$		-0.35**						-0.12*	-0.04
		(0.26)						(0.33)	(0.06)
lnPUB$_{it}$			0.16***					0.13**	0.12****
			(0.06)					(0.06)	(0.01)
lnPUB$_{jt}$			0.20**					0.26**	0.18****
			(0.08)					(0.10)	(0.03)
lnDST$_{ij}$	-0.13***	-0.13***	-0.13***					-0.10**	-0.13****
	(0.04)	(0.04)	(0.04)					(0.04)	(0.03)
dLANG$_{ij}$				0.05				0.03	0.05*
				(0.04)				(0.04)	(0.03)
dCOL$_{ij}$					0.06			0.07*	0.07**
					(0.04)			(0.04)	(0.03)
dMEM$_{ij}$						0.14*		-0.09	-0.01
						(0.08)		(0.08)	(0.05)
lnTRD$_{ijt}$							0.04**	0.03*	0.03****
							(0.02)	(0.02)	(0.01)
Constant	1.84	2.20	-1.20	0.66	0.73	0.75	0.68	15.67	-0.34
	(10.05)	(3.25)	0.97	(10.05)	(10.05)	(10.04)	(10.05)	(10.85)	(0.94)
R^2 (%)	88.92	89.26	89.68	88.40	88.41	88.52	88.85	96.05	81.95
R^2 adj (%)	88.63	88.98	89.41	88.10	88.11	88.22	88.57	95.61	80.83
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Country Pairs-FE	No	No	No	No	No	No	No	No	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
No. Obsv	1584	1584	1584	1584	1584	1584	1584	1584	1584

Robust standard errors are reported in parentheses.

**** p<0.001; *** p<0.01; ** p < 0.05; *p < 0.1

APPENDIX II: ESTIMATION RESULTS OF POISSON REGRESSION WITH COUNTRY-PAIR FE AND YEAR FE, 2006–2016

Variable	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16	Model 17	Model 9
lnPOP$_{it}$	0.01			0.01	0.01	0.01	0.01	-0.01	0.01
	(0.04)			(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
lnPOP$_{jt}$	-0.02			0.02	0.02	0.02	0.04	-0.78	0.02
	(0.59)			(0.60)	(0.59)	(0.59)	(0.59)	(0.65)	(0.03)
lnGDPC$_{it}$		-0.37***						-0.33*	-0.01
		(0.16)						(0.17)	(0.03)
lnGDPC$_{jt}$		-0.34***						-0.13*	-0.04
		(0.26)						(0.33)	(0.06)
lnPUB$_{it}$			0.16***					0.13**	0.12****
			(0.06)					(0.06)	(0.01)
lnPUB$_{jt}$			0.20**					0.26**	0.18****
			(0.08)					(0.10)	(0.03)
lnDST$_{ij}$	0.55	-0.32	-0.09					0.68	-0.13****
	(1.26)	(0.40)	(0.25)					(1.41)	(0.03)
dLANG$_{ij}$				0.03				0.07	0.05*
				(0.35)				(0.35)	(0.03)
dCOL$_{ij}$					-0.15			-2.39	0.07**
					(0.56)			(1.85)	(0.03)
dMEM$_{ij}$						0.63		0.23	-0.01
						(0.56)		(1.06)	(0.05)
lnTRD$_{ijt}$							0.03	0.03	0.03****
							(0.04)	(0.04)	(0.01)
Constant	-3.54*	3.97	-1.33	1.01	1.05	1.05	0.91	9.51	-0.34
	(1.82)	(5.49)	(1.78)	(10.06)	(10.05)	(10.05)	(10.05)	(6.31)	(0.94)
R^2 (%)	95.27	95.64	96.04	95.26	95.27	95.26	95.31	96.38	81.95
R^2 adj (%)	94.75	95.17	95.61	94.74	94.75	94.75	94.80	95.97	80.83
Country FE	No	No	No	No	No	No	No	No	No
Country Pairs-FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
No Obsv	1584	1584	1584	1584	1584	1584	1584	1584	1584

Robust standard errors are reported in parentheses.
**** p<0.001; *** p<0.01; ** p < 0.05; *p < 0.1

APPENDIX III: ESTIMATION RESULTS OF TWO-YEARS LAGGED VARIABLES FE AND THREE-YEARS LAGGED VARIABLES FE 2006–2016

	Model 21	Model 22
$\ln INTRA_{it-1}$	0.687	0.636
	(0.495)	(0.481)
$\ln EXTRA_{it-1}$	0.561	0.028
	(0.454)	(0.405)
$TRDr_{it-1}$	0.352	0.139
	(0.226)	(0.195)
$EDUr_{it-1}$	0.114	0.092
	(0.143)	(0.138)
$R\&Dr_{it-1}$	-0.003	0.215
	(0.452)	(0.561)
$\ln FDI_{it-1}$	0.048	-0.120
	(0.085)	(0.074)
$\ln LAB_{it-1}$	0.939	3.124
	(1.953)	(1.901)
$GDPc_{it-1}$	2.036**	4.262****
	(1.126)	(1.197)
$BUSenv_{it-1}$	2.091****	1.863****
	(0.541)	(0.486)
Constant	17.555	45.162
	(19.314)	(30.004)
R-squared (%)	98.8	98.9
Adj.R-Squared (%)	98.3	98.3
Year FE	Yes	Yes
Country FE	Yes	Yes
No. Obsv	81	72

Robust standard errors are reported in parentheses.
**** p <0.001; *** p <0.01; ** p < 0.05; *p < 0.1
Source: Author

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