PHD

Essays on innovation and corruption : a cross-country analysis

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Award date:
2020

Awarding institution:
University of Bath

ESSAYS ON INNOVATION AND CORRUPTION: A CROSS-COUNTRY ANALYSIS

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A Thesis Submitted for the Degree of
Doctor of Philosophy
University of Bath
Department of Economics

July 2019

Signature: Date

قال تعالى:

﴿ ادْعُواْ رَبَّكُمْ تَضَرُّعًا وَخُفْيَةً إِنَّهُ لاَ يُحِبُّ الْمُعْتَدِينَ * وَلاَ تُفْسِدُواْ فِي الأَرْضِ بَعْدَ إِصْلاَحِهَا وَادْعُوهُ خَوْفًا وَطَمَعًا إِنَّ رَحْمَتَ اللهِ قَرِيبٌ مِّنَ الْمُحْسِنِينَ ﴾

{سورة الأعراف 55-56}.

ALLAH The Highest Says:

”(55) Call upon your Lord in humility and privately; indeed, He does not like transgressors. (56) And cause not corruption upon the earth after its reformation. And invoke Him in fear and aspiration. Indeed, the mercy of Allah is near to the doers of good”

Surah Al-A'raaf (55-56)

ACKNOWLEDGEMENTS

I praise Allah SWT for giving me the strength and courage to complete this thesis.

This thesis is the output of four years of my life; and I would like to take this opportunity to express my most genuine appreciation to all the people who helped me throughout this journey. As someone told me once, ‘PhD is another name of stress’, and while at times I was optimistic, there have been times during which I despaired, and these people have always present and encouraged me to keep up the hard work.

I would like to express my deepest gratitude to my late supervisor **Professor John Hudson**, may his soul rest in peace. He always encouraged me through this journey. He helped me for more than two years and I feel very fortunate to have him as a supervisor; my friends used to call him my academic father. Also, I would like to sincerely thank my supervisors, **Dr.Ajit Mishra** and **Dr.Imran Shah**, for their support to improve my academic skills and to successfully complete this work during the final year of my research.

Also, I would like to thank my external and internal examiners, **Dr .Ahmad Hassan Ahmad** from Loughborough University and **Dr. Bruce Morley** for their effort and helpful feedback in improving the quality of this thesis.

It is an honour for me to thank the Oman Government that sponsored me to complete my further education. This work would not have been possible without their financial support.

Finally, I would like to express my deepest gratitude to my family, especially my mother ‘**Sharifa’** and my late father **’Mohamed’** – May his soul rest in peace – who passed away during the first stage of this journey. My parents have always encouraged me to obtain higher education degrees. Furthermore, I would like to express my appreciation to all my siblings and their children. Special thanks go to my special sister **’Sumaiya ’** and my favourite brother **’Yousuf ’** who have always been by my side at all the stages of my life: “Your endless support, patience, and encouragement have been my most precious tools for facing the challenges I have encountered throughout my nascent career". A very special thank you goes to my favourite nephew **'Abdulmalik'.**

Last but not least, I am sincerely thankful to all my friends for being were there for me throughout my PhD journey. I would like to take the opportunity to mention them by name: **Ruqaiya Al-Jabri**, **Noha Naji**, **Tayiba Al-Hilali**, **Sozy Mohamed**, **Salwa Al-Jabri**, **Sarah Jasem** and **Bayan Alkhawaja**, for there endless support.

Without your ongoing support, this thesis would not exist
Thank you

ABSTRACT

Although the connection between innovation and corruption has been ubiquitous since the middle of the twentieth century, scholars have yet to establish an exact nature of this relationship: some researchers have found that corruption can boost the innovation level via removing the rigid obstacles to investment and foster innovation which eventually greases economic growth. Conversely, others demonstrated that corruption could deter innovation levels and the adverse relationship between corruption and innovation can slow down economic growth. This complex and controversial relationship encouraged us to further investigate the interaction between the two across many countries and over several years. To this aim, our first empirical chapter addresses the relationship between corruption and innovation. Unlike usual approaches, we apply two proxies to represent innovation and they are divided into: 1) innovation inputs, where a fixed effects method has been used, and 2) innovation outputs, where a random effects method has been used. The results show that corruption could sand the wheel of innovation inputs, yet, it shows no impact on innovation outputs. In conclusion, innovation inputs are adversely affected by corruption. Therefore, governments should establish anti-corruption campaigns as well as focus on minimizing corruption by implementing laws and regulations that discourage any attempts to corruption.

The second empirical paper studies the effect of neighbouring corruption on home country innovation and, furthermore, examines neighbouring innovation impact on the home country corruption. Two Stages Least Squares method and random effects method have been used respectively to address these issues. The empirical evidence demonstrates that neighbouring corruption harms home innovation, as well as being adversely affected by neighbouring innovation. Additionally, geographical closeness between capital cities can increase corruption in both countries (neighbour and home country). Also, neighbouring openness acts as a hindrance to home country corruption, and it can help reduce corruption. Thus, we can conclude that countries can be affected by their neighbours' levels of corruption, and that it is challenging to remain uncorrupted while surrounded by corrupted countries. To minimize the harmful effect of contagious corruption on home innovation therefore, governments should set strict laws and regulations at the borders.

The third paper empirically investigates the influences of English Language, trade openness and corruption on innovation outputs, namely on research productivity, by using mixed models. Our empirical results show that both trade openness and corruption are adversely related to research productivity. However, the results also demonstrate that countries which have English as an official language are more active in the research field in terms of citations than those countries in which English is not an official language. On the other hand, in terms of publications the results showed that countries with English as an official language are not necessarily publishing more than those where English is not an official language. Therefore, governments should firstly support international and national grants by increasing the amount dedicated to the R&D sector, and secondly should also encourage international collaboration.

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GLOSSARY

R&D	Research & Development
CPI	Corruption Perception Index
TI	Transparency International
GDP	Gross Domestic Product
US $	United States dollar
PPP	Purchasing Power Parity
MENA	Middle East and North Africa
NA	North America
ESP	East Asia and Pacific
ECA	Europe and Central Asia
LA	Latin America
SSA	South Asia and Sub-Saharan Africa
Rnd	Research & development
Pat	Patents
Researchers	Researchers
Articles	Articles
Corp	Corruption
Pop	Country Size (,000,000,000)
Hc	Human Capital (,000,000)
Capita	GDP per Capita (0,000)
Trade	Trade Openness
Nat	Natural Resources rent
WCI	Worst Country Incidents
Rnd	Innovation
Corp	Corruption
Aveninnov	Average Innovation of the neighbouring countries
Avencorp	Average corruption level on the neighbouring countries

Nat	Natural Resources
GDP	Log GDP
avedist2	Geographical Closeness
Average	Average trade of the neighbouring countries
Avenfdiout	Average FDI outflow of the neighbouring countries
Lock	Landlocked dummy
d20**	Year Dummy
no*	Number of Neighbours Dummy
Docs	Number of Documents
Cites	Number of Citations
Cpd	Citations Per Document
L21	English Language
Trade	Trade openness
Corp	Corruption Perception Index
Rd	Research & Development
Pop	Country size
Gdp	Gross Domestic Product, ppp
Capita	GDP per Capita, ppp
d1996-d2018	Year dummy (1996-2018)

1. Chapter One: Introduction

1.1 Purpose of the Study

This research project explores the corruption-innovation relationship over time. Specifically, the thesis aims to contribute to the corruption and innovation literature by providing a more comprehensive view of how this complicated relationship is manifested across countries and over time. Thus, the following aims and objectives have been developed for the present project:

1. ***Examine the relationship between innovation and corruption***. The first objective of this study is to address the overall relationship between corruption and innovation through the two main categories of input and output. Innovation input is represented by the research & development expenditures and the number of researchers working in the research & development sector while the innovation output is signified by the number of residential patents and the number of articles published.

2. ***Quantify the impact of contagious corruption on the home country innovation***. The second objective of this study is to explore if the corruption of neighbouring countries has an impact on the innovation level in the home country. Also, this part discusses if the innovation of the neighbouring countries can affect the level of corruption in the home country.

3. ***Address the relationship between innovation (research productivity) and the use of English as an official language.*** The final objective of this study is to investigate if English "being an official language" has an impact on a country's innovation level represented by research productivity. The variables used to characterize the research productivity are the number of citations, of publications and citations per publication. Other variables, including corruption are also being controlled.

1.2 Thesis Outline

This PhD research is structured as an article-based thesis comprised of a context chapter that sets the scene for the study, and three separate articles written for publication in three different journals. Each of these articles raises distinct research questions and presents independent contributions to the literature. They are closely interlinked and complementary as each one addresses a specific aspect of the primary objective of the thesis to explore and understand the dynamic relationship between corruption and innovation. The thesis ends with general conclusions, research limitation and suggested future work. The structure flowchart of the thesis is as illustrated in Figure (1-1).

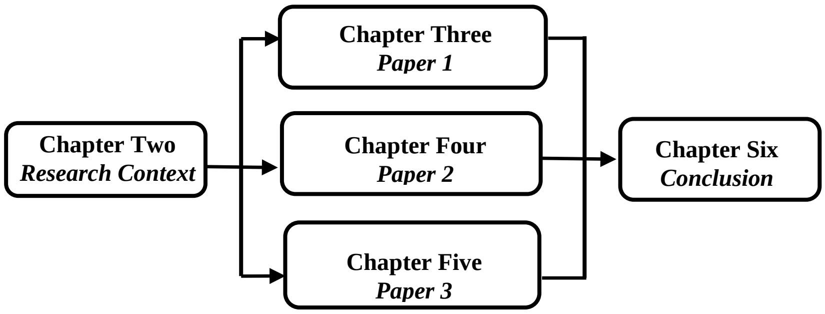


Figure 1-1. Thesis Structure Flowchart

Chapter 2: ***Research Background-*** This chapter delivers an overview of the economic growth theory. It also provides definitions of the two main eras of this project, which are innovation and corruption and their relationship to the economic growth of nations.

Chapter 3: ***Paper 1-*** Chapter 3 presents the first article, entitled "Is Corruption Detrimental to Innovation?" The purpose of this paper is to map the corruption-innovation conflict relationship, and to identify the research gaps that require further attention. Therefore, this paper proposes to investigate the relationship between corruption and both innovation inputs and outputs for selected countries over several years while controlling other variables. Overall, the results showed that corruption impairs the level of innovation.

Chapter 4: ***Paper 2*****-** This presents the second article, entitled “Does Contagious Corruption affects Home innovation?” This paper is an extension of the previous paper and to the best of the researchers’ knowledge it is the first to investigate the question of whether neighbouring corruption can disturb home country innovation level .Goel and Nelson (2007) and many others studied if corruption can move from one place to another and they concluded that corruption could be contagious. Thus far, this chapter is based on the country level, and it aims to quantify the influence level on the home country’s innovation of the neighbouring countries’ corruption. Geographical proximity was the main factor used to quantify the impact of corruption and, interestingly, the results showed that corruption could move from a country to another and it can harm the innovation level in the home country.

Chapter 5***: Paper 3*****-** Chapter 5 presents the last article, entitled “Can Corruption Distress Research Productivity?” This study attempts mainly to empirically investigate if countries with English as an official language are more innovative than countries in which English is not an official language. Furthermore, this article meant to quantify the impact of corruption level on the research productivity of nations. However, to the best of the researcher’s knowledge, this is the first attempt to quantify these impacts using 170 countries for 23 years. The results support that countries in which English is an official language neither have the advantage nor the disadvantage to be more innovative in terms of research productivity.

Chapter 6: ***Conclusion*****-** Chapter 6 provides an overall conclusion to the three papers and mentions the implications of this research, its limitations and future directions.

2. Chapter Two: Research Context

This chapter is divided into two sections that provide an overview of the research context. Section 2.1 highlights the research background, defining the thesis' two main focuses of innovation and corruption. This will be followed by a brief summary of the literature on the relationship between innovation and corruption.

2.1 Research Background

The economic growth of a nation can be influenced either by endogenous or exogenous factors such as human capital, natural resources, and technological change. The scholars of economic growth theories have branched into two different schools of theories along the line of this division. Firstly, traditional economic growth theories such as Neo-classical economic growth models represented by the Neoclassicist school such as Ramsey (1928), Solow (1956) and Swan (1956) who theorised that exogenous factors drive economic growth. The second school of the recent economic growth theories built around Schumpeterian economic growth theory whose core principle is that economic growth or development is driven endogenously through technological change. In this context, innovation is considered to be an endogenous factor which affects economic growth within in a system (Schumpeter, 1939:38). The following section provides more details about innovation and its relation with economic growth.

2.1.1 Innovation

The common definition of innovation involves developing new ideas in order to yield new programs, new processes or ways, new products, or new services. Generally, all innovations commence with generating original ideas. Amabile et al. (1996) defined innovation as successfully implementing creative ideas. According to West and Altink (1996), "innovation is any idea, practice or material artefact perceived to be new by the relevant unit of adoption". Furthermore, Kanter (1983) defines innovation as "the process of bringing any new problem-solving idea into use".

However, the theory of economic growth has evolved over years to appear in its current shape. Since the recognition of the relationship between technological progress, innovation and economic performance in the 1990s, investment in research and development has snowballed along with the widening of innovation activities across many sectors of the economy (OCDE, 2000). Furthermore, innovation is a crucial factor in development both because it is one of the economic growth's main drivers (OECD, 2012), and because it helps address socio-economic challenges. Much of the literature has established that innovation has a vital role in stimulating either the growth of a country's economy — not only in developed countries, but also in emerging ones — or a firm's profitability (Cameron, 1996; Sachs and McArthur, 2002; Bilbao-Osorio and Rodríguez-Pose, 2004; Rosenberg, 2004; Fagerberg et al., 2010; Galindo and Méndez-Picazo, 2013; Fan, 2014). Thus, innovation has been increasingly studied over the last five decades because of its importance for the economic development of nations. Based on the economic scholarly literature, Solow (1956), Mansfield (1972), and Nadiri (1993) theoretically and empirically examined how innovation contributes to the economic growth of nations. Drawing on this literature, therefore, innovation is selected in this study to be the primary independent variable. Figure (2-1) shows the growth trend of the world's Gross Domestic Product (GDP)[1] and Innovation[2], using the average data of 178 countries over the period 2000-2016[3]. According to Figure (2-1), the global GDP is distinctly increasing, yet the spending in R&D is fluctuating from one year to another. During the period of 2000-2015, the spending in R&D has increased by 23 % despite the fact that the global GDP has increased by 71% since 2000.

[1] GDP is constant in 2011 prices and at Purchase Power Parity.
[2] Innovation is represented in research and development expenditure (R&D) and it is a proportion of GDP.
[3] The data of GDP and R&D are averages of the countries which are used in this thesis.

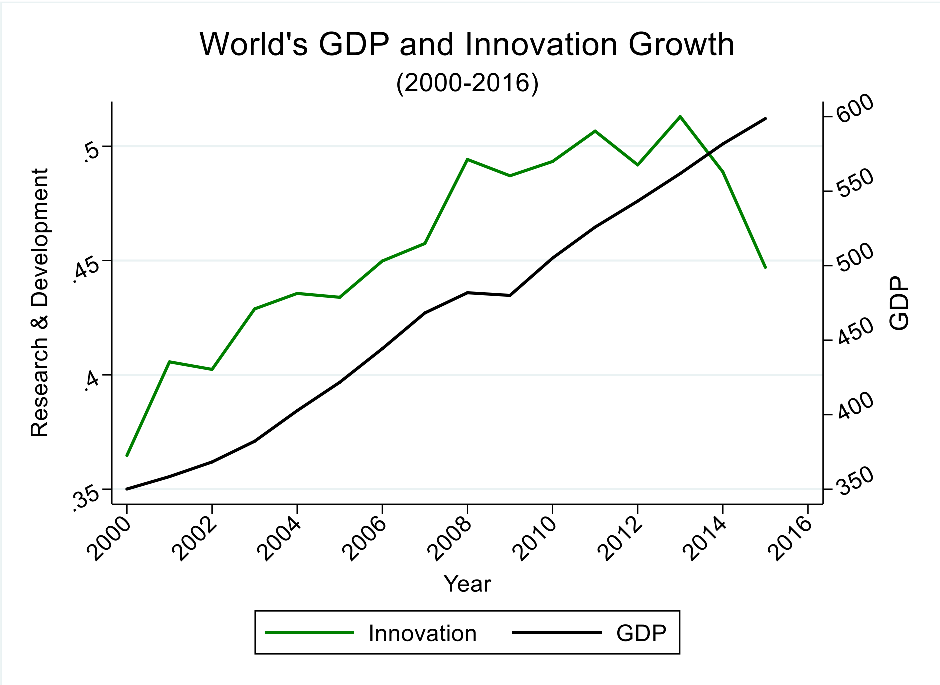


Figure 2-1. Global GDP vs. Global R&D
Source. World Bank

Additionally, Figure (2-2) shows World's R&D expenditure in 2015 and demonstrates that countries which have a similar spending on innovation are neighbours. This relationship has further encouraged us to focus on innovation and investigate more deeply the knowledge spillover which might be due to several reasons including the location of a country, its common language, common culture or any other reasons.

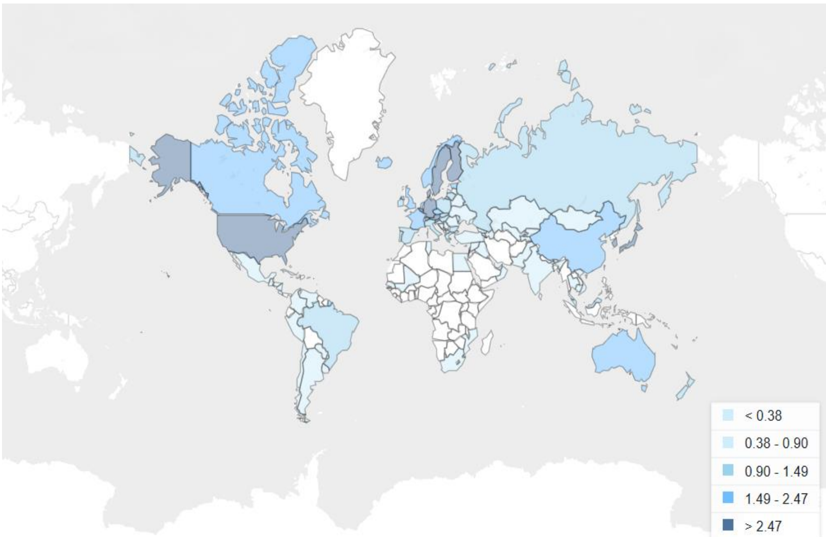


Figure 2-2. World's R&D expenditures 2015
Source: World Bank.

2.1.2 Corruption

Corruption becomes an increasingly interesting factor for many researchers in different fields, each of which has defined it in different ways. According to the World Bank, the most prevalent definition of corruption is that it is the abuse of public power for private benefit. Transparency International (TI) has defined corruption as “the abuse of entrusted power for private gain which eventually hurts everyone who depends on the integrity of people in a position of authority”. Regarding the cost of corruption, the United Nation (2018) stated that it is around 5 percent of the Global GDP. This means that trillions of dollars are being spent for corruption activities every year, being paid in bribery, nepotism, theft and other illegal forms (United Nations, 2018). Therefore, corruption is a serious problem for almost every country, especially those in the developing and emerging economies. According to Transparency International[4], more than 65% of the countries which are included in the organization’s surveys and are considered corrupt, are facing a serious corruption issue because they score below 50 on the Corruption Perception index (CPI). The rest of the countries are considered to be clean, and although they do have some corruption activities, it is a small value compared to corrupt countries. Figure (2-3) shows the trend of global corruption[5] over the period of 2000 to 2017, which was illustrated by taking the average of the corruption of countries included in the present thesis over each year. It is clearly visible that the world’s corruption level increases over the time, and the worst year was 2010, in which the average corruption index was approximately 60 points in a scale of 100.

[4] Transparency International is the leading global responsible organization in fighting against corruption.

[5] In this research study, we reversed the index so that it ranges from 100 (highly corrupt) to 1 (very clean).

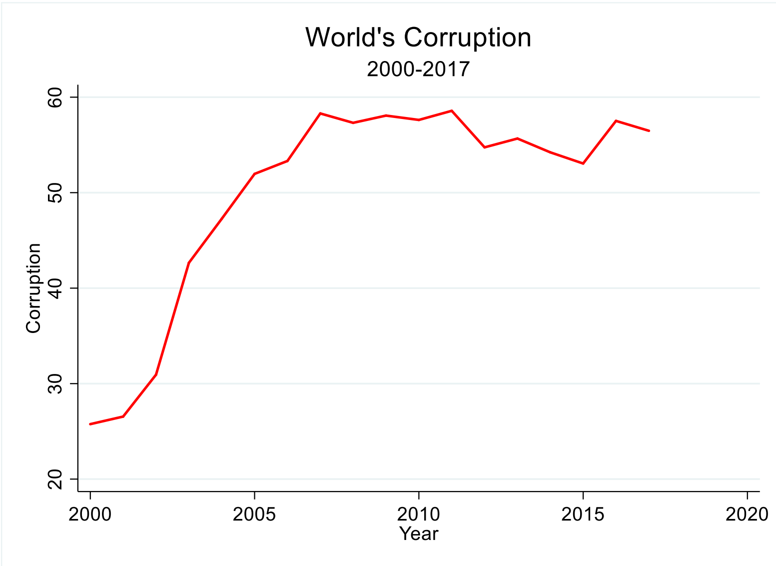
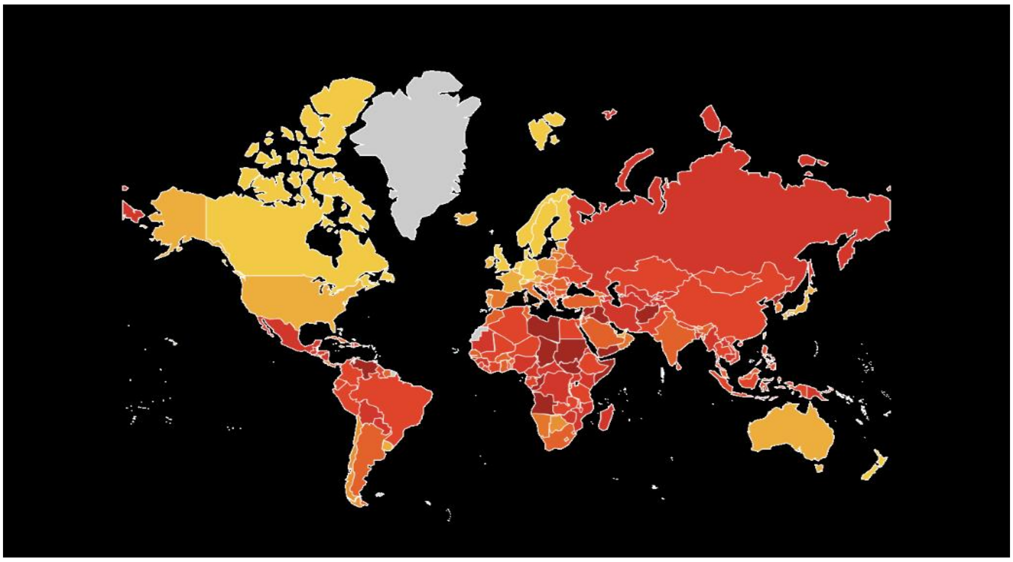


Figure 2-3. World Corruption Growth Trend
Source. Transparency International

Figure (2-4) illustrates the world’s corruption in 2018, indicating that corrupted countries are clustered together and clean countries are also gathered together. This trend of cohesion encouraged us to study contagious corruption by investigating the reasons behind this infection and its impact on neighbouring countries economic growth. We claim that corruption infection can affect home country innovation through affecting home country corruption. We argue that the contiguity of corruption among countries can harm the innovation of a home country which impacts the growth of a country’s economy.



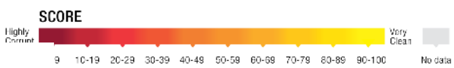


Figure 2-4. World's Corruption 2018
Source: Transparency International Organization

Corruption is considered as one of the most challenging features for many economies around the world, yet, the literature has not achieved a firm agreement regarding the effect of corruption on economic growth. On the one hand, some researchers claim that corruption is beneficial to the growth of an economy when it is efficient because it can help speed up unnecessary bureaucratic procedures to overcome the distortion policies and thus boost official governmental performance (Mauro, 1995; Aidt, 2003). On the other hand, other researchers have provided evidence that corruption might be desirable and that it boosts the wheel of economic development and growth (Leff, 1964b; Huntington, 1968; Tanzi and Davoodi, 2000; Mahagaonkar, 2008; Wang and You, 2012; Nguyen et al., 2016).

However, most of the literature has reported that corruption can be considered an obstacle to economic growth and development because it decelerates the economic wheel (Murphy et al., 1993; Mauro, 1995; Rose-Ackerman, 1999; Acemoglu and Verdier, 2000; Acemoglu et al., 2001; Mo, 2001; Lambsdorff, 2002; Rock and Bonnett, 2004; Anokhin and Schulze, 2009; Heckelman and Powell, 2010; Lau et al., 2015). Many researchers have attempted to explore the relationship between corruption and the economic development of the nations through the GDP per capita (La Porta et al., 1999; Treisman, 2000; Okada and Samreth, 2012).

Figure 2-5 shows the average of 178 countries' distribution between corruption and economic wealth, represented in GDP per capita between the period 2000-2017. The graph shows a clear adverse association between corruption and GDP per capita in which countries with more corruption level have a lower GDP per capita (i.e. countries with a higher level of GDP per capita are cleaner).The graph also makes it apparent that developing countries are clustered at the end of the chart, while the wealthier nations are at the top and the beginning of the scale (cleaner countries). In sum, we can conclude that although countries which have less corruption tend to have a higher GDP per capita compared to the countries with a higher level of corruption, we cannot generalize this to all countries. For instance, Kuwait and Qatar which have high GDP per capita are corrupted compared to Singapore which is less corrupted with less GDP per capita.

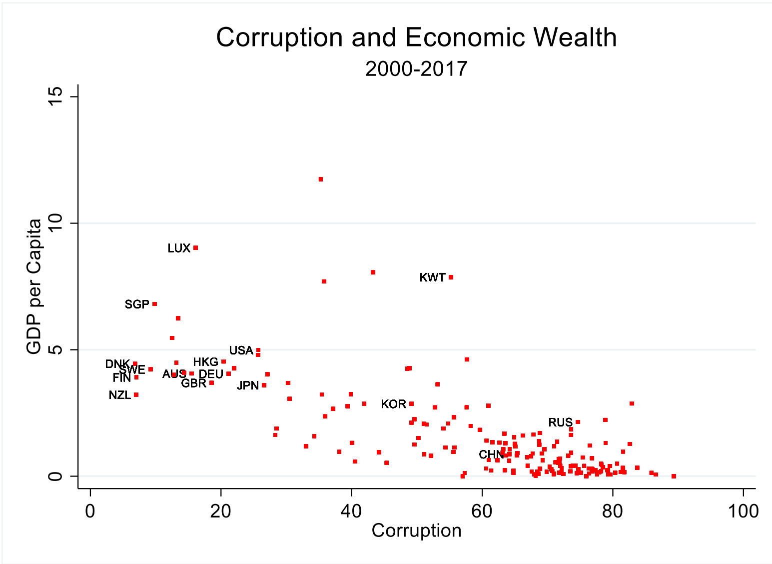


Figure 2-5. The relationship between Corruption and Economic Wealth
Source. World Bank

2.2 Innovation and Corruption

Goel and Nelson (2007) have stated that corruption as a social and economic problem has persisted since time immemorial. However, due to the limited nature and diversity of empirical evidence regarding the influence of corruption on innovation, not many studies reveal a clear relationship between innovation and corruption at the country level. Moreover, researchers have never reached an explicit agreement on whether corruption is beneficial or detrimental to innovation. Due to the ambiguous relationships associated with data limitations for conducting studies in order to compute the direct influences of corruption on innovation activities, the results of existing empirical projects are divergent. Some studies have found that corruption is an impediment, while others consider it as a boost to innovation. For instance, results by Lau et al. (2015) demonstrate that corruption is positively related to innovation, which is proxied by the number of patent applications. This result is consistent with Bayley (1966) and Leff (1964a), confirming that corruption may help remove rigid obstacles to investment and foster innovation which can eventually grease the economic wheel. Likewise, Mahagaonkar (2008) demonstrated that corruption has a positive effect on marketing innovation. Still, Johari and Ibrahim (2017) have examined the effect of innovation on corruption levels, and their results revealed that when the country is considered innovative with high levels of innovation, neither people nor businesses will have the incentive to be corrupted through bribing precisely because they are focusing on innovation in order to gain competitive advantage. In simple words, innovation can help a country to be less corrupt.

Rather differently, and in the same study, Mahagaonkar (2008) found that corruption has an adverse effect on product innovation and organisational innovation. Additionally, using macro level data for 64 countries Anokhin and Schulze (2009) concluded that corruption is detrimental to innovation. Furthermore, Smith et al. (2014) empirically examined the same relationship on the micro-level using multi-national firms, institutions and innovation in Russia. They found that in environments with high political risk — in corrupt environments — corruption may act as a hedge against such risk, boosting the scope and scale of innovation.

According to the World Bank indicators statistics (World Bank, 2019), innovation is growing on a slow and steady rate which is shown in terms of R&D expenditures in Figure (2-6). R&D expenditures have increased by almost 23%. Conversely, the corruption level fluctuates at an increasing rate during the same period and increases

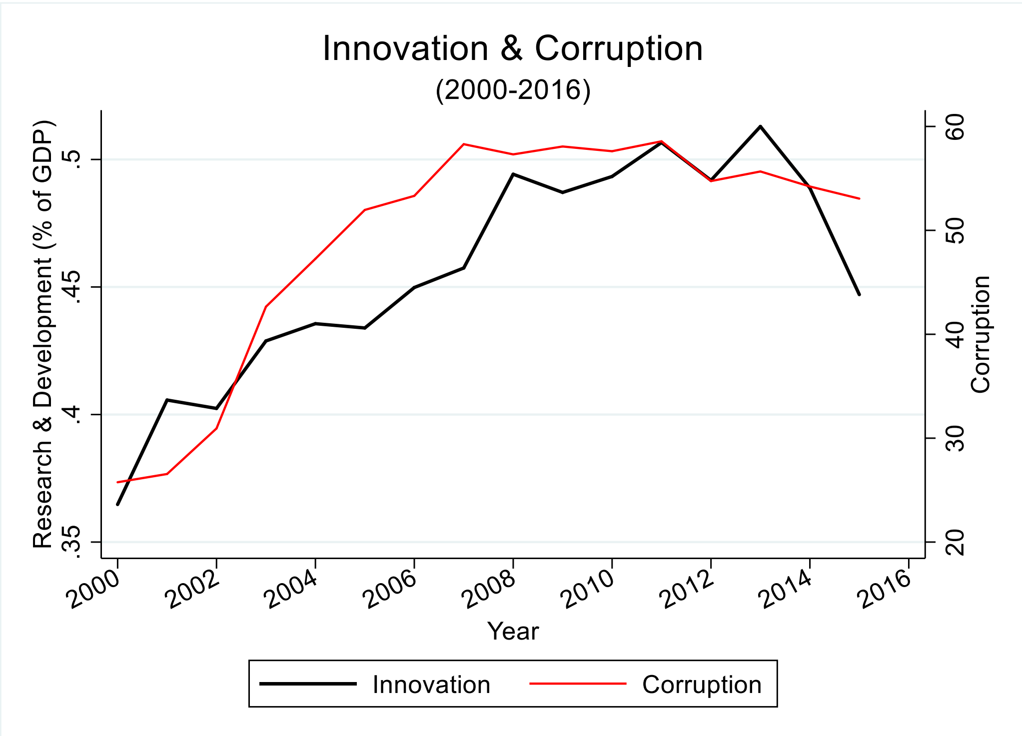


Figure 2-6. World's Corruption vs. World's Innovation

noticeably by more than 100% for 15 years only — between 2000 and 2015 —, which means that the world is going towards more corruption.

2.3 The Three Papers

The final section of the context chapter presents extended abstracts for each of the three papers that compose this thesis. The abstracts provide an overview of the studies' objectives, methods, findings and contributions.

2.3.1 Papers' Abstracts

2.3.1.1 Paper 1: Is Corruption Detrimental to Innovation?

Although the relationship between corruption and innovation has been the object of scrutiny, existing research has not yielded any conclusive results regarding the influence of corruption on innovation. The unavailability of data in this regard has spurred this thesis to carry out further investigations to explore this influence. Unlike usual approaches, we apply four proxies to represent innovation for 176 countries over a period of 18 years (2000-2017). These proxies are divided into two main categories: 1) innovation inputs (i.e. R&D expenditures and researchers working in research and development sectors), and 2) innovation outputs (i.e. residential patents and the number of journals and articles published). A fixed effects model is used for innovation inputs, while for innovation outputs, we used random effects. The results show that corruption could sand the wheel of innovation inputs such that when the corruption index is raised by 1 point both the R&D expenditure and the number of researchers decreased by 0.0056 percentage points and 0.0105 researchers (per million), respectively. However, corruption shows no impact on innovation outputs. In conclusion, innovation inputs are adversely affected by corruption. Nevertheless, this is not the case for the Sub Saharan Africa region, where corruption can grease innovation activities. Therefore, the governments shall firstly focus on anti-corruption campaigns as the effectiveness of these has been demonstrated, and they secondly shall concern themselves with setting rules and regulations in order to reduce corruption levels in countries.

2.3.1.2 Paper 2: Does Contagious Corruption Affect Home Innovation?

Innovation is a key pillar in the economic growth of nations. However, previous studies show that home county innovation can be affected by home corruption that is contagious and can travel from one country to another. This paper empirically investigates the effect of neighbouring corruption on home country innovation using a dataset of 140 countries over the period of 2003 to 2017. To address this issue, we use the Two Stages Least Squares (2SLS) method and to address the impact of neighbouring innovation on home corruption, we use random effect technique. Our empirical evidence demonstrates that neighbouring corruption negatively affects home innovation, as well as being adversely affected by neighbouring innovation. Also, geographical proximity results show that closeness between capital cities can make increase corruption rates in both countries and also impair their innovative efforts. Furthermore, neighbouring openness acts as an obstacle to home country corruption, and it can help in reducing corruption. Thus, we can conclude that countries can be affected corresponding to their neighbours, and hence, it is challenging to remain uncorrupted while surrounded by corrupt countries. Therefore, governments should construct laws and regulations to reduce contagious corruption.

2.3.1.3 Paper 3: Can Corruption Distress Research Productivity?

Research productivity is a key output of innovation activities. Publications are considered to be the main determinant of research productivity, and more than 50 million documents have been published worldwide for the last 23 years. However, the factors of trade openness and English Language might have an impact on published documents. For this reason, this study empirically examines the influences of these factors on research productivity levels, using mixed models, the Hierarchal linear model, for 170 selected countries over the period of 1996-2018. This study, furthermore, has considered the factor of corruption. The results show that research productivity was negatively affected by trade openness and corruption in an adverse relationship. Even though countries where English is the official language have a higher level of research activity in terms of citations compared to countries with official languages other than English, the latter were not necessarily publishing less than their counterparts. Therefore, the governments should encourage the researchers to translate locally published documents into English because English is the global language (Northrup, 2013) so that a local piece of work can be internationally exposed

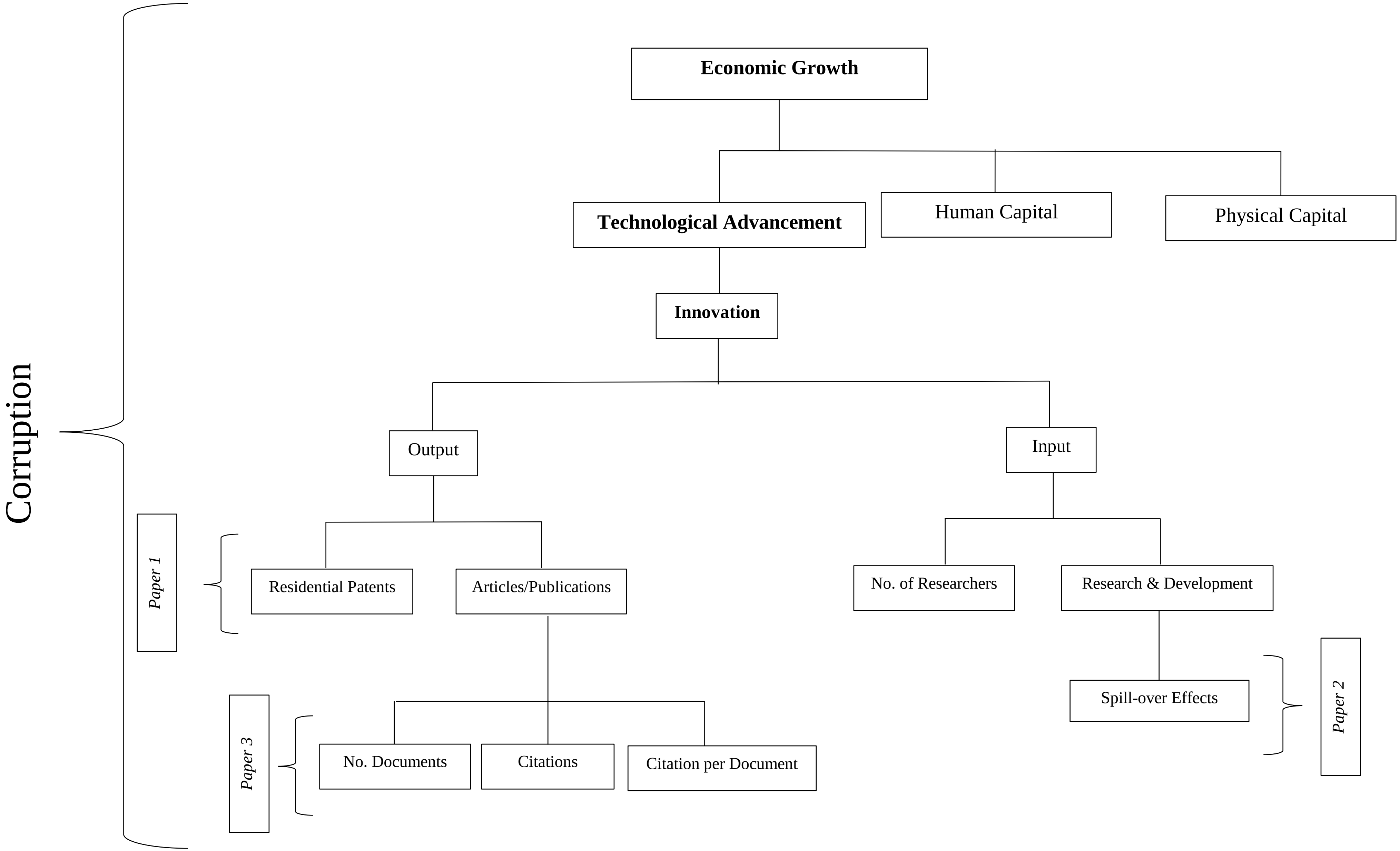


Figure 2-7. Illustration of the Thesis

2.4 Chapter Summary

The objective of this chapter was threefold. First, it aimed at presenting an overview of the main two main elements in this thesis. Second, it reflected the conflict relationship between innovation and corruption using the related literature. Finally, the chapter provided extended abstracts of the papers included in the thesis, and also highlighted the interrelationship among them.

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This declaration concerns the article entitled:									
Is corruption detrimental to innovation?									
Publication status (tick one)									
Draft manuscript	X	**Submitted**		**In review**		**Accepted**		**Published**	
Publication details (reference)									
Copyright status (tick the appropriate statement)									
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3. Chapter Three: Is Corruption Detrimental to Innovation?

3.1 Abstract

This paper intends to examine the influence of corruption on innovation as the existing literature has not yielded conclusive results in this regard. Four proxies have been used to represent innovation, which are divided into two main categories: 1) innovation inputs (i.e. R&D expenditures and researchers working in research and development sectors), and 2) innovation outputs (i.e. residential patents and the number of journals and articles published). A fixed effects model is used for innovation inputs, while for innovation outputs, we used random effects. The results show that innovation inputs are adversely affected by corruption while, corruption has no control over innovation outputs. Although this is not the case for sub Saharan countries where corruption is found to fuel innovation activities. Establishing anti-corruption campaigns were demonstrated to be effective, hence it's recommended that governments should focus on setting such rules and regulations in order to reduce corruption, which eventually can help innovation to flourish.

Keywords: Innovation, Corruption, Fixed Effects, Random Effects

3.2 Introduction

Innovation is one of the sophisticated features of economic growth and Schumpeter (1934) was the first to introduce the importance of innovation regrading economic growth. Indeed, it was stated to be the primary driver of countries' economic growth (Nelson and Winter, 1982; Romer, 1990; G. M. Grossman and Helpman, 1993; Pece et al., 2015; Broughel and Thierer, 2019). Cirera and Maloney (2017) adopt Schumpeter's description of innovation, albeit in a broader view. According to these researchers, innovation is "the ability to use knowledge to develop and apply new ideas that result in changes in the production and organisational structure"[6]. In 2018 the United Nations have reported that corruption costs the world more than two trillion dollars annually, or 5% of the global GDP, while those resources could be reallocated for innovation. However, corruption is an intricate phenomenon, and its impact on innovation is realised both at macro and micro levels (Bicchieri and Ganegonda, 2016; Dimant and Schulte, 2016). The micro-level investigation took the largest share of the corruption and innovation literature (de Waldemar, 2012; Wang and You, 2012; Smith et al., 2014; Nguyen et al., 2016; Habiyaremye and Raymond, 2018), while this effect is largely overlooked at the macro level.

However, economists have addressed the relationship between innovation and corruption on macro and micro levels despite the ambiguous findings. DiRienzo and Das (2015) find that innovation can be badly harmed by corruption, yet at varied levels, meaning that unlike in poor countries, the effect of corruption is mitigated in the wealthier countries. Therefore, some countries focused on controlling corruption levels in order to help innovation to flourish (Anokhin and Schulze, 2009). According to the World Bank (2008), nations' institutional foundations needs to sustain and promote innovation are being weakened by corruption despite the form of corruption[7]. Johari and Ibrahim (2017) conclude that innovation can help countries to reduce corruption through focusing on innovation so that the private sectors can become less reliant on nepotism. In a recent study

[6] The concept of innovation is discussed further in Chapter 1 in "The innovation paradox: Developing-country capabilities and the unrealized promise of technological catch-up" by Cirera and Maloney (2017).
[7] For more elaboration of forms of corruption see Morris (2011).

introduced by Dincer (2019), who investigates the long-run relationship between corruption and innovation activities, it is found that corruption indeed slows down innovation in the long run. Some governments, such as that in China, emphasise anti-corruption activities[8] which helps firms to innovate more by increasing their investment in research and development (R&D) (Dang and Yang, 2016; Gan and Xu, 2018) and generate more patents (Xu and Yano, 2017).

In contrast to this interpretation, Nguyen et al. (2016) hypothesise that innovation activities can be greased by corruption by means of overcoming the ineffectiveness of the public sector with the help of small informal fees (bribes), and Mahagaonkar (2008) suggests that corruption facilitates innovation in marketing[9]. Furthermore, Wang and You (2012) stress the greasing effect of corruption on firms' growth in China which eventually leads to the economic growth of the nation. All these researchers support Leff's (1964) argument about corruption being rent-seeking rather than a hindrance.

The results of existing empirical studies to compute the direct influence of corruption on innovation activities are divergent mainly due to the complicated relationships associated with data limitations for conducting these studies. Consequently, researchers never reached an explicit agreement on whether corruption is beneficial or detrimental to innovation. For example, some researchers have found that corruption is an impediment, and others see it as a boost to innovation (Mahagaonkar, 2008; Veracierto, 2008; Habiyaremye and Raymond, 2013; Smith et al., 2014; Goedhuys et al., 2016; Gan and Xu, 2018). The current study aims to fill the gap in the literature by studying the relationship between corruption and innovation at macro level, with the focus on the greasing and sanding hypothesis.

The objective of this study is threefold. First, we examine the relationship between corruption and innovation inputs represented by (R&D) expenditures and the number of researchers using a cross-country data set of 176 countries over 18 years (2000-2017). Secondly, we investigate the same relationship yet with innovation

[8] Please refer to (Wedeman*, 2005) for eclectic analysis of the anti-corruption campaigns.
[9] For more details see (Mahagaonkar, 2008)

outputs (residential patents and articles published)[10]. Thirdly, we compare these relationships in all seven regions around the world, namely, in East Asia and Pacific, Europe and Central Asia, Latin America, Middle East and North Africa, North America, South Asia and Sub-Saharan Africa[11] in order to investigate if the country's location matters in light of the relationship between corruption and innovation. In order to fulfill the objectives of this study we have used a cross-country data set of 176 countries over 18 years (2000-2017). Based on the Hausman test, the fixed effects model is considered to be a suitable method to quantify the influence of corruption on innovation inputs. Furthermore, random effects is an appropriate method to examine the impact of corruption on innovation outputs.

This study offers three unique contributions to the literature. Firstly, this paper seeks to contribute to the empirical literature of innovation and corruption, as it provides a cross country empirical analysis of how corruption distresses innovation activities. Although this effect has been investigated on a smaller scale of countries by previous empirical studies[12], this paper uses a larger scale of countries which gives general, comprehensive and more confident results. While most of the previous literature focused on measuring the impact of corruption on the micro-level (firms), this study has carried out a macro level (countries) investigation. Secondly, this paper adds to the literature by measuring the impact of the same controlled factor, corruption, on the level of innovation inputs and outputs together which have not been considered in previous studies using four proxies of innovation. The employment of four proxies is intended to check the validity, robustness and consistency of the results. To this end, we have used two related but different proxies representing the innovation inputs and outputs as the results of the number of researchers should justify the results of R&D. Finally, this study contributes to the literature by showing through regional comparison the influence of countries' geographical location on the relationship between innovation and corruption, which has not been addressed yet. During this comparison, we examine

[10] These variables are elaborated in section 6.
[11] The division of the regions is based on the World Bank division
[12] For example DiRienzo and Das (2015) who used 113 countries

the combined effect of corruption on the level of innovation for all the seven regions.

On the one hand, the results regarding innovation inputs confirm the conclusion that innovation can be harmed by corruption (i.e. countries with a higher level of corruption tend to invest less in the innovation sector). On the other hand, and differently from Lau et al. (2015), the results related to innovation outputs show an insignificant influence of corruption (i.e. corruption has no impact on the innovation outputs). Furthermore, the results of the East Asia and Pacific regions are consistent with the national level results, namely that corruption sands innovation activities. At the same time however, the Sub-Saharan Africa region, including the corrupt countries in our sample, shows that corruption can facilitate innovation.

The rest of the study is organised as follows. The next section discusses the link between innovation and corruption according to previous theoretical and empirical studies. Section 4 gives a detailed explanation of the theoretical framework. Section 5 explains the methodology and it is followed by the description of the data and variables in section 6. Section 7 gives a comprehensive interpretation and analysis of the results along with a discussion of these. Section 8 provides the conclusion of the chapter, and finally, section 9 details the limitations of the research project and avenues of future research.

3.3 Literature Review

There is a considerable amount of empirical literature along with some theoretical literature that discusses how corruption affects economic growth. Bayley (1966) and Leff (1964) support the hypothesis that corruption such as bribes and nepotism (favoritism) can grease the wheel of economic growth through removing the rigid obstacles which lead to investing more in firms at micro level. At the end of the chain this can aid the innovation to flourish at macro level. With reference to innovation, it is well established in the economic literature that innovation is the key driver for nations to grow at a faster pace. However, corruption can influence economic growth via several channels such as political stability and human capital (Dridi, 2013). Innovation was proposed by many as one of the channels through which corruption can affect economic growth directly or indirectly. However, a thorough study of the empirical connection between the two was not carried out at the macro level (Mahagaonkar, 2008). There is no clear consensus in the literature as to whether the impact of corruption is beneficial or detrimental to innovation either on macro or at micro level. Hence, a complex relationship between them has led to limitations in data required for studying the direct influence of corruption upon innovation.

There are several empirical pieces of the literature that investigate the relationship between innovation and corruption, yet a clear relationship between these two variables is not elucidated at the macro-level. Some have found that corruption is an impediment, while others consider it as a boost to innovation. Mo (2001); Bentzen (2012) and Dridi (2013) provide empirical evidence on how corruption sands the economic growth wheel by hampering private investment which negatively affects the productivity levels of countries. Per contra, Mendoza et al. (2015) and Mahagaonkar (2008) provide empirical evidence that corruption can accelerate the innovation level especially in developing countries where the quality of governance is poor, through overcoming the bureaucratic obstacles. However, researchers in this field pay more attention to the micro-level, in particular the firm level. Goedhuys et al. (2016) find that corruption has a direct adverse effect on the likelihood that a firm is an innovator and conclude that corruption has a positive effect on institutional obstacles. Additionally, Fisman and Svensson (2007), De Rosa et al. (2010) and de Waldemar (2012) provide evidence that corruption[13] sands a firm's growth. Similarly, Mahagaonkar (2008) finds that corruption can be a hindrance to organisational and product innovation[14]. Thus, corruption interrupts innovation directly via several channels, the allocation of the resources being the primary and most evident one. In contrast, corruption can hasten innovation by overcoming the bureaucratic procedures such as bribes, small fees, payments and nepotism. This is argued by Mahagaonkar (2008) and Habiyaremye and Raymond (2013) who confirm the hypothesis that corruption can facilitate innovation, and in particular, the marketing innovation, of firms. Besides this, Lau et al. (2015) support

[13] Bribery is used as an indication of corruption.
[14] For more details see (Mahagaonkar, 2008). Furthermore, he depended on the OECD (2005) manual on innovation types.

the argument that corruption along with investing in the education sector (in human capital) can grease the wheel of innovation through generating more patent applications and innovation output. Mendoza et al. (2015) support the idea of corruption greasing the wheels of economic growth via Philippine SMEs, particularly in cities with poor business environments[15]. However, other researchers examine the relationship between innovation and corruption from the perspective of anti-corruption campaigns. Gan and Xu (2018) claim that environments with stronger anti-corruption efforts encourage firms to invest more in the R&D sector. Furthermore, firms which are in a high political risk environment could benefit from corruption, which may act as a hedge against such risk by boosting the scope and scale of innovation (Smith et al., 2014).

The Europe and Central Asia region were mentioned more frequently than the other six regions of the world in the literature on corruption and innovation[16] (Lau et al., 2015). The literature on innovation for the rest of the regions is less abundant than that on the impact of corruption on innovation in the Middle East and Northern Africa (MENA) regions which, in particular, is limited and relatively obsolete (Helmy, 2013). Therefore, there is a need to investigate the assumption that corruption hinders innovation empirically. In this context, we take the approach that corruption is a barrier to innovation because corruption, as discussed previously, has negative economical and ethical consequences (Habib and Zurawicki, 2002). Therefore, our focus in this paper is to assess empirically the ways in which corruption could impact the level of innovation in the seven regions of the world.

The literature examines other variables for their impact on the innovation level, in both the input and output innovation forms. For instance, Bloom et al. (2016), Akcigit et al. (2018) and Chen et al. (2018) use trade openness to address its relationship with innovation and they notice that the more open the country is to trade, the more innovative it is. We have added GDP per capita as economy scale

[15] Bribes can either put ‘grease’ or ‘sand’ in the wheels of commerce, affecting firm performance (at the micro-level) and, ultimately, economic growth (at the macro-level). This study examines this issue using a unique and exceptionally rich dataset on over 2000 micro, small and medium scale enterprises in over 30 cities in the Philippines.

[16] I think it is due to the availability of the data and most of the countries within this region are developed countries.

for the countries included in this paper and researchers have concluded that countries with higher GDP per capita tend to innovate more (Papageorgiadis and Sharma, 2016; Paunov, 2016)[17]. Country size is used as a proxy for the population to examine the impact of populated countries on the innovation (Papageorgiadis and Sharma, 2016) and they find that country size is positively significant with the innovation level in that countries with more population tend to be more innovative. Moreover, Dakhli and De Clercq (2004), Lau et al. (2015) and van Uden et al. (2017), addressing the question of whether the size of the human capital can have an impact on innovation, conclude that human capital is important for the countries to innovate.

Corruption, therefore, can grease innovation activities via overcoming any unnecessary bureaucratic practices in governmental offices and can thus lead the economies of the nations to grow. However, logically, corruption sands innovation activities via increasing the costs, in terms of the reallocating of resources, and via impairing the trust between public officials and people. Besides, corruption is considered to be an unethical practice regardless of the reason for practicing it. This paper debates the suggestion that corruption hinders innovation activities via reallocating innovation inputs that decelerate innovation outputs. Consequently, the wheel of the economic growth is to be sanded.

3.4 Theoretical Framework

Corruption can affect the portion of resources allocated to innovation activities, that is to the research and development sector of a business. The devoted resources are continually allocated to bribes that businessmen have to pay in order for them to enter the market, regardless of whether they fulfill the requirements to being in the market or not. This means that the amount of resources dedicated to innovation activities is reduced in corruption activities (Acemoglu and Verdier, 2000; Veracierto, 2008). This can result in a misallocation of the resources for corruption activities. Corrupt environments can also provide disincentives for investors

[17] Papageorgiadis and Sharma (2016) concluded that as the real GDP per capita increases, the innovation output—patents— obtained more.

(entrepreneurs) to invest in these kinds of environments because there is no fair competition in the market.

Consider a group of n firms, competing in the market, choosing the amount of R&D expenditures $d_i, i = 1,2, \dots, n$. Suppose that R&D leads to a reduction in the production cost of the firm, in which:

$$C_i = c(d_i), \quad c' < 0 \tag{3-1}$$

Where C_i is the production cost in a function of R&D expenditures (d_i), c' is the marginal cost of R&D expenditures, meaning that the cost decreasing.

Suppose that the inverse market demand be as follows:

$$P = a - bq \tag{3-2}$$

Where P is the market price, a is the chock-off price with $a > 0$ — parameter indicator of economic activities —, b is the slope of the inversed market and q is the total output supplied (consumed) market which is given by:

$$q = q_1 + q_2, \qquad n = 2 \tag{3-3}$$

Where $q_1$is the quantity supplied by firm 1 and q_2 is the quantity supplied by firm 2.

We consider a scenario where firms chose d_i in period 1 and after cost realization at the end of period 1, choose quantities q_i in period 2. For simplicity, there is no discounting.

In period 2, firms compete in a Cournot fashion and profits (π) are given by: [18]

$$\pi_i = \frac{\left(a - 2C_i + C_j\right)^2}{9b} \qquad i, j = 1,2 \tag{3-4}$$

[18] It can be applied to most models of competition. This is only for illustration.

In period 1, the total payoff is given by:

$$V_i = \pi_i\,(d_i) - x(d_i) = \pi_i\,(d_i) - x.d_i \qquad (3\text{-}5)$$

Where V_i is the total pay-off, $\pi_i\,(d_i)$ is the profit (revenue) and $x(d_i)$ is the cost. Since $\pi_i(d_i)$ is increasing and concave in d_i, we can find the optimum amount of expenditure ${d_i}^*$. In fact, firm1's expenditure d_1 will also depend on firm2's R&D expenditure and we can have a case of strategic complementarity[19]. Ignoring this fact, the total expenditure can be expressed as follows:

$$d_i^* = d_1^* + d_2^* \qquad (3\text{-}6)$$

More appropriately, d_i can be interpreted as R&D activity and x is the per unit cost. For example, x can be seen as the cost of hiring scientists/ researchers or the cost of setting up and running a scientific laboratory. For developing countries, x is likely to be high. It can be shown in Figure (3-1) that the demand for R&D activity is a decreasing function of x. At the same time however, for a large market, higher a, d^* will be higher[20]. This is because the marginal benefit of extra spending on d_i will be higher.

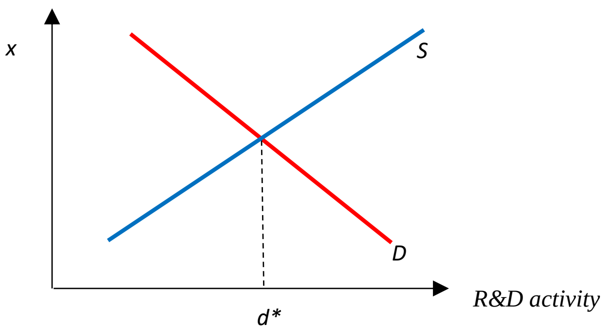

Figure 3-1. Market of R&D activity

At the other end of the market, we have a household deciding whether to become scientists/researchers. A simple occupational model can be used to show that the supply of R&D activity will be an increasing function of x. This is assuming that returns from other occupations stay the same. In poorer countries, this supply could

[19] Higher d_i leads to more investment by 2 and so on.
[20] Richer Countries will have higher "a"

be a vertical straight line if the supply of human capital is low and occupation choice is constrained.

Corruption affects both sides of the market. First, households will find that other occupations (bureaucrats) are likely to be more lucrative, and this will invariably lead to an inward shift in supply. Consequently, the economy will have fewer scientists/researchers[21]. For firms, however, the effect is varied. Corruption undermines competition in a way that firm i investing in corrupt practices can have a bigger market share or is able to enjoy monopoly status by bribing officials. As mentioned previously, this leads to resources being diverted (Acemoglu and Verdier, 2000; Veracierto, 2008). R&D activities will thus decrease, which also leads to an inward shift in demand. Figure ((3-2) (case A)) shows how corruption leads to a reduction in R&D activities (innovation) in the presence of corruption. But corruption can facilitate investment also in certain cases as shown in Figure ((3-2) (case B)). For example, if x is the cost of importing scientific equipment and there are restrictions in place, x is likely to be very high. With corruption, these constraints can be avoided. Likewise, unnecessary regulations may stifle economic activities and corruption can open up these markets. This can be interpreted as an increase in parameter a, leading to an outward shift in demand as shown in Figure ((3-2) (case B)).

[21] This argument was put forward by Shleifer and Vishny (2002) in their “Allocation of Talent: Implications for Growth” chapter in “The Grabbing Hand” book

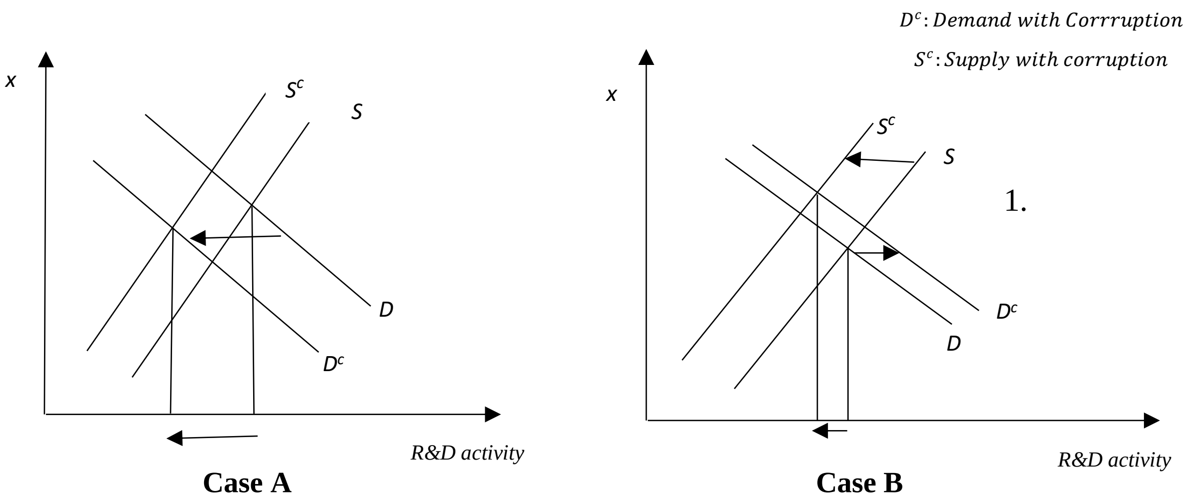

Figure 3-2. The effect of Corruption in R&D market

However, this does not mean that equilibrium innovation activities will be higher. Overall, the equilibrium will depend on the strength of variance forces. However, our empirical exercise aims to pin this down.

To summarise, corruption can affect the innovation level in countries by lowering the rate of product innovation in an organisation (private or public). If many industries have corrupt practices this will result in a fall in the organisation's innovation level, which consequently affects the whole economic growth of the nation.

3.5 Methodology

We carry out an analysis to investigate the impact of corruption on the level of innovation. Beside this paper's main variables of corruption and innovation, we also consider several other variables which might influence innovation. Hence, we use unbalanced panel data for 176 countries over the period between 2000 and 2017.

The general panel model is given by equation (3-7).

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \quad (3\text{-}7)$$

where $\boldsymbol{Y}$ signifies the innovation level represented by innovation inputs (i.e. R&D and number of researchers) and innovation outputs (i.e. patents and articles published). The X vector represents our main variable which is corruption beside other exogenous variables[22]. The number of countries (176 countries) studied in this paper is represented by $\boldsymbol{i}$ while $\boldsymbol{t}$ represents the time frame (2000 to 2017).

There are four models to be estimated in this paper, which are given as follows:

$$\begin{aligned} rnd_{it} = \ & \beta_i + \beta_{1it}\, corp_{1it} + \beta_{2it}\, pop_{2it} + \beta_{3it}\, hc_{3it} \\ & + \beta_{4it}\, capita_{4it} + \ \beta_{5it} trade_{5it} + \ \beta_{6it}\, nat_{6it} \\ & + \ \gamma_{7it} WCI_{7it} + \mu_{it} \end{aligned} \tag{3-8}$$

where *rnd* signifies research & development expenditures, *corp* represents corruption, *pop* is the country size, *capita* signifies GDP per capita, *trade* indicates trade openness, *nat* denotes natural resources and *WCI* signifies to worst corruption incidents dummy variable.

$$\begin{aligned} & researchers_{it} \\ & \quad = \beta_i + \beta_{1it}\, corp_{1it} + \beta_{2it}\, pop_{2it} + \beta_{3it}\, hc_{3it} \\ & \quad + \beta_{4it}\, capita_{4it} + \beta_{5it} nat_{5it} + \gamma_{6it} WCI_{6it} + \ \mu_{it} \end{aligned} \tag{3-9}$$

where *researchers* signifies number of researchers working in the R&D sector (per million), *corp* represents corruption, *pop* is the country size, *hc* denotes human capital, *capita* signifies GDP per capita, *nat* symbolizes natural resources and *WCI* signifies to worst corruption incidents dummy variable.

$$\begin{aligned} pat_{it} = \ & \beta_i + \beta_{1it}\, corp_{1it} + \beta_{2it}\, pop_{2it} + \beta_{3it} rnd_{3it} \\ & + \beta_{4it} researchers_{4it} + \beta_{5it} articles_{5it} \\ & + \beta_{6it} nat_{6it} + \beta_{7it} capita_{7it} + \gamma_{8it} WCI_{8it} + \mu_{it} \end{aligned} \tag{3-10}$$

where *pat* signifies number of patents, *corp* represents corruption, *pop* is the country size, *rnd* symbolizes research & development expenditures, *researchers*

[22] The variables are elaborated in detail in section 6 of this chapter.

indicates the number of researchers working in the R&D sector, *articles* denotes to the number of articles published, *capita* signifies GDP per capita, *nat* symbolizes natural resources and *WCI* signifies the worst corruption incidents dummy variable.

$$articles_{it} = \beta_i + \beta_{1it}corp_{1it} + \beta_{2it}capita_{2it} + \beta_{3it}researchers_{3it} + \beta_{5it}nat_{5it} + \gamma_{5it}WCI_{5it} + \mu_{it} \quad (3\text{-}11)$$

where *articles* signifies the number of articles published, *corp* represents corruption, *capita* signifies GDP per capita, *researchers* indicates to the number of researchers working in the R&D sector, *nat* symbolizes natural resources and *WCI* signifies the worst corruption incidents dummy variable.

3.5.1 Fixed Effects Model

For Models (3-8) and (3-9), where the dependent variables are R&D and the number of researchers, respectively, the fixed effects model is satisfactory according to the Hausman test results, as given in Table (3-1). The fixed effects model is considered to be a reasonable model to investigate the impact of corruption, along with other variables, on innovation inputs. The fixed effects model can be written as (3-12):

$$Y_{it} = \alpha_i + \gamma_1 x_{1it} + \gamma_2 x_{2it} + \cdots + \gamma_k x_{kit} + \mu_{it} \quad (3\text{-}12)$$

where *Y* signifies the R&D and number of researchers. $\boldsymbol{\alpha}$ is the intercept which differs for each country. *x* indicates the independent variables which are shown in Models (3-8) and (3-9). $\boldsymbol{\mu}$ is the error term. *i* indicates the countries included in this study (176 countries) while *t* represents the time period of this study (2000-2017).

3.5.2 Random Effects Model

According to the Hausman test results, the random effects model is the satisfactory model for (3-10) and (3-11) Models where the dependent variables are the number of patents and articles published. These variables are regressed using random effects model. The random effects model can be expressed as (3-13):

$$Y_{it} = \alpha + \gamma_1 x_{1it} + \gamma_2 x_{2it} + \cdots + \gamma_k x_{kit} + (\varepsilon_i + \mu_{it}) \qquad (3\text{-}13)$$

where *Y* signifies the patents and number of articles. $\boldsymbol{\alpha}$ is constant for all countries. *x* indicates the independent variables which are given in Models (3-10) and (3-11). $\boldsymbol{\mu}$ is the error term and $\boldsymbol{\varepsilon}$ is the standard random variable which differs for each country, *i* indicates the country (176 countries) while *t* indicates the time (the period of the study) as 2000–2017.

3.5.3 Hausman Test

In order to choose the most suitable approach between fixed effects and random effects— for the four Models (3-8), (3-9), (3-10) and (3-11), the Hausman test is used (Hausman, 1978) because its main objective is to help to decide between fixed effects or random effects, the, where the null hypothesis. Ho states that the random effects model is more appropriate than the fixed effects because random effect are consistent and efficient. H1: the fixed effects will always be consistent. The Hausman test principally examines whether the error terms are correlated with the explanatory variables or not. For the panel data, the appropriate choice between the fixed effects and the random effects methods investigates whether the regressors are correlated with the individual (in most cases unobserved) effect. The Hausman test uses the following test statistics:

$$\boldsymbol{H} = \left(\widehat{\boldsymbol{\beta}}^{\boldsymbol{FE}} - \widehat{\boldsymbol{\beta}}^{\boldsymbol{RE}}\right)' \left[\boldsymbol{Var}\left(\widehat{\boldsymbol{\beta}}^{\boldsymbol{FE}}\right) - \boldsymbol{Var}\left(\widehat{\boldsymbol{\beta}}^{\boldsymbol{RE}}\right)\right]^{-\boldsymbol{1}} \left(\widehat{\boldsymbol{\beta}}^{\boldsymbol{FE}} - \widehat{\boldsymbol{\beta}}^{\boldsymbol{RE}}\right) \sim \boldsymbol{x}^{\boldsymbol{2}}(\boldsymbol{k}) \qquad \textit{(3-14)}$$

In other words, the key difference between the fixed effects model and the random effects model for testing panel data is that the first model assumes that each country of our sample has its own intercept α_i , as shown in Model (3-12), whereas the random effects model adopts the idea that each country differs in its standard random variable ε_i , as shown in Model (3-13).

3.5.4 Durbin Wu-Hausman Test (DWH)

While no a specific test to check endogeneity exists, there is a technique which helps us to check if one of the independent variables is correlated with the dependent variable error term by using the Durbin Wu Hausman test. This test compares the coefficients of Ordinary Least Squares (OLS) and the Two Stages Least squares (2SLS) (in other words, the null hypothesis states that the preferred estimator is the OLS) (Hausman, 1978). However, the test results support the application of the OLS technique for all four models precisely because of our inability to reject the null hypothesis and conclusion that FE and RE are the appropriate methods for the four models[23].

3.6 Variables Description and Data Source

This section presents the variables used in this paper which consist of three sub-sections. The first sub-section discusses in detail the dependent and independent variables as well as the logic intuition behind including them in the model. This is followed by a brief description of the sample of the study and the sources of the data. The third sub-section discusses the stationarity level of all variables using the unit root test.

3.6.1 The Variables

3.6.1.1 The Dependent Variable

Innovation is a crucial factor for development both in less advanced countries and advanced ones (Cirera and Maloney, 2017). It is a well-established stylised fact within the literature that innovation contributes to the economic growth of nations, as stated by Schumpeter (1912), Solow (1956) Mansfield (1972), King and Levine (1993), Nadiri (1993), Ulku (2004) Aghion et al. (2005) and Adak (2015), who have examined it both theoretically and empirically. The level of innovation shows how a country can capture the multi-dimensional aspects of innovation that promote policies in order to encourage long-term growth. The dependent variable in this

[23] DWH test is explained in more details in Chapter 4 of this thesis.

study is innovation, yet there is no strictly defined theory on the determinants of innovation. The simplest procedure in determining the level of innovation is to find approaches that can capture the richness of innovation in a country. Therefore, it is very important to detect the determinants of innovation in order to enhance economic growth by planning operative policies. The use of innovation as the dependent variable was motivated by the literature (Mahagaonkar, 2008). Increasingly, studies have begun to investigate the ways in which innovation can be measured or quantified either on a national-level or firm-level, and the well-known and traditional measure of innovation that has mainly been used by researchers is the number of patents. Furthermore, according to Morck and Yeung (2001), innovation can be measured by three quantitative measures: 1) number of patents, 2) innovation counts, and 3) research and development spending. Moreover, Fan (2014) considered that patent statistics, research and development inputs, paper citations and new product announcements can be used to measure or quantify the level of innovation.

Investing in research and development has a positive influence on the number of patents in both developed countries (Furman and Hayes, 2004) and developing countries (Hu and Mathews, 2005). Continuous investment in R&D is essential for innovation. Countries with strong commitments towards innovation and significant investment in R&D achieve relatively high levels of innovation. Figure (3-3), which uses World Bank data to reveal a non-linear positive relationship between R&D expenditures and the number of patents across countries. Furthermore, the figure reveals that the innovation level of countries represented by the number of patents rise at an fast rate when the R&D expenditure increases. Consequently, the more investments occur in R&D expenditure, the more patents can be established (Varsakelis, 2006; Artz et al., 2010; Czarnitzki and Hussinger, 2018).

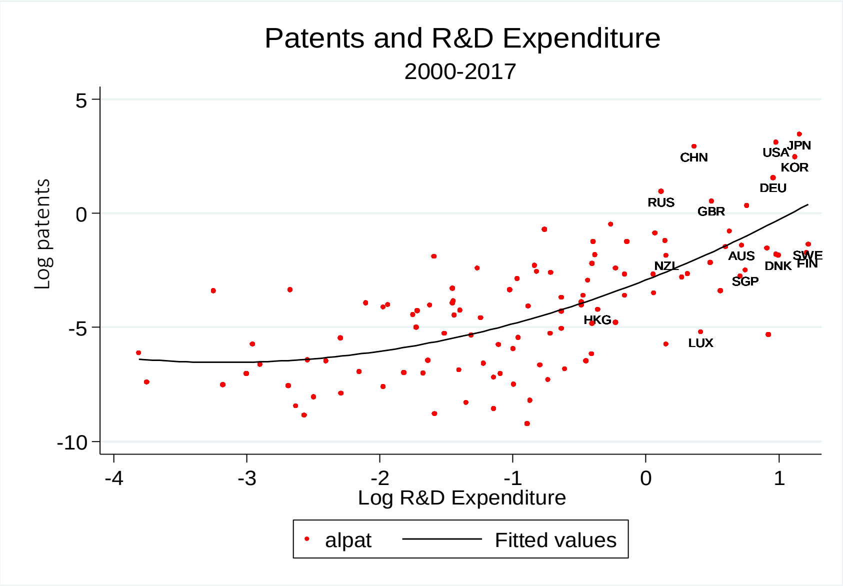

Figure 3-3. The relationship between research and development expenditure and Patents
Source: World Bank data

Based on the literature, innovation function has been measured using different features either by inputs such as R&D expenditures and number of researchers, or by outputs such as patents and articles published[24] (Cirera and Maloney, 2017). In the case of this paper, the level of innovation is measured using the same input and output measures. The following section introduces the dependent variables that represent the level of innovation.

3.6.1.1.1 Innovation inputs

1. Research and Development

The World Bank defines R&D as the "current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge including knowledge of humanity, culture, and society, as well as the use of knowledge for new applications". R&D is one of the main ways to gain a competitive advantage in science and technology for both the government and private sector. This aspect reflects the extent to which a country allocates resources for growing the overall stock of knowledge including fundamental research, applied

[24] Cirera and Maloney (2017) have explained in detail the innovation function in terms of its inputs and outputs in The innovation paradox: Developing-country capabilities and the unrealized promise of technological catch-up- Chapter 2.

research and experimental development work leading to new devices, products or processes. in detail expenditure is considered to be one of the most important elements in improving the innovation capacity both of nations and firms (Audretsch and Feldman, 2004). Therefore, the R&D expenditure is the main output measure proxy of innovation, which is measured as a proportion of the GDP of each country. The R&D expenditure variable has been considered in many studies as an innovation input (Furman et al., 2002; Bottazzi and Peri, 2003; Hu and Mathews, 2005; Varsakelis, 2006; Smith et al., 2014; Lau et al., 2015).

2. Researchers (Per Million)

The number of researchers variable according to the World Bank refers to "the number of personnel (researchers and technicians) in the research and development sector who are professionals engaged in the conception of new knowledge, products, processes, methods, or systems. Data on researchers in R&D are measured as full-time equivalent. The data are obtained through statistical surveys that are regularly conducted at national level covering R&D performing entities in the private and public sectors". In this paper, we are considering the number of hired researchers as a dependent variable representing the level of the innovation of a country (Cohen and Levinthal, 1990; Flatten et al., 2011).

3.6.1.1.2 Innovation outputs

1. Patents

The number of patents variable refers to residential patents where the first-named applicant or assignee is a resident of the state or region concerned. Patent data is a great resource in the study of technical change in a country or region. The number of residential patents is used to quantify the level of innovation. However, the number of residential patents has been accepted as the most appropriate and most common measure in quantifying the level of innovation capability (Acs et al., 2002; Furman et al., 2002; Cheung and Ping, 2004; Hu and Mathews, 2005; Varsakelis, 2006; Anokhin and Schulze, 2009; Fan, 2014; Smith et al., 2014; Lau et al., 2015; Igami and Subrahmanyam, 2019). The number of patents is a valid measure for tapping a country's innovative output because this measure captures an important aspect of the level of technological activity, and because several fundamental conditions need to be fulfilled in order for an activity or invention to qualify for patent eligibility (Crosby, 2000; Varsakelis, 2001; Hu and Mathews, 2005).

2. Scientific and Technical Journal Articles

This variable refers to an absolute number of scientific and engineering articles published in peer reviewed journals in each country. Hu and Mathews (2005) used this variable as an independent one, yet it has not been used broadly as the representation of innovation level. Thomas et al. (2011) have used it as the outcome of the R&D process, where R&D is considered as an innovation input. Therefore, in this paper, the number of publications is treated as an innovation output (Katz, 2016).

3.6.1.2 The independent variables

In addition to our principal factor, corruption, we control for other variables that are expected to be important factors of innovation. The choice of explanatory variables is inspired by the related empirical and theoretical literature as well as the availability of data.

1. Corruption

This variable is designed to emphasise the misuse of public office for private or personal benefit. Transparency International, the "global civil society organization leading the fight against corruption", pointed out that corruption is difficult to capture because it happens "behind closed doors and underneath the tables" (Smith et al., 2014). Subsequently, measuring corruption directly and quantifying it has proven to be a daunting task. There are several indexes measuring corruption, such as Control of Corruption Index (CCI), Public Integrity Index (PII) and others25, yet they suffer from a high correlation issue (Heywood, 2015). We are using Corruption Perception Index (CPI) which is the most widely accepted measure of corruption (Heywood, 2015). Furthermore, it is "an index claiming to capture the informed views of analysis, business people and experts around the world on corruption in

[25] For more details see (Heywood, 2015)

different countries". Transparency International is the organisation responsible for collecting corruption data. Even though certain academics claim that CPI lacks objectivity because it measures individuals' perceptions of the level of corruption in a particular country, it is generally accepted as the best corruption measure that the international community has identified (Mo, 2001; Varsakelis, 2006; Mahagaonkar, 2008; Veracierto, 2008; Anokhin and Schulze, 2009; Lau et al., 2015; C.-J. Huang, 2016; Ali *et al.*, 2019; Kimhi and Oliel, 2019).

Transparency International measures the perceptions of corruption on a scale of 0 to 100, with 0 indicating the highest level of corruption and 100 indicating the lowest. But, for the purpose of this paper and to avoid any confusion, we reversed the scale, so that 0 indicates the lowest level of corruption (i.e. clean countries) and 100 indicates the highest level of corruption (i.e. highly corrupt countries).

2. Human Capital

Coleman (1988) has defined the human capital concept as "individuals' knowledge and abilities that allow for changes in action". Education plays a critical role in developing the innovative capability of a country. The level and standard of education and research activity in a country are prime determinants of the innovation capacity of a nation. Human capital may be developed through formal training and education aimed at updating and renewing one's capabilities in order to do well in society. The most vital component in a nation's innovation scheme is the learning ability of individuals, firms and countries (Lundvall et al., 2002). The argument regarding the human capital variable is that the level of educated people can affect the level of innovation i.e. a lower number of educated people in a country can hold back the level of innovation in that country. Furthermore, this variable is being used widely to measure the labor force in a nation or a company (Dakhli and De Clercq, 2004; Hu and Mathews, 2005; van Uden et al., 2017). The expected relationship between this variable and the innovation level is positive.

For this paper, to proxy for human capital, the Educational Attainment for Population Aged 25 and over data has been utilised (Barro and Lee, 2013) [26]. Barro

[26]Data extracted from http://barrolee.com/data/oup_download_c.htm,

and Lee has updated their data until 2040 at 5 years intervals and as they stated, “Our estimates of educational attainment provide a reasonable proxy for the stock of human capital for a broad group of countries and should be useful for a variety of empirical work”. Due to the availability of the data by 5-year intervals, interpolation has been employed to forecast the observations for the missing years.

3. *Country Size*

This variable is included in terms of total population as a control variable since country-level innovation is also affected by the number of people within a country. Larger countries are characterised by more extensive exchange of all types of resources at multiple levels. Therefore, larger countries may generate more patents, be involved in more R&D expenditures, and have more high-tech export compared to smaller countries even in per capita terms. In addition, we included population because it indicates the scale of workers that are potentially available for innovative activity. We are interested in the potential production of innovative output relative to national population, therefore, we are including this variable where it is necessary, such as in Models (3-8), (3-9) and (3-10) (Furman et al., 2002; Bottazzi and Peri, 2003; Dakhli and De Clercq, 2004; Hu and Mathews, 2005; Anokhin and Schulze, 2009; Papageorgiadis and Sharma, 2016).

4. *Trade openness*

The data of trade openness is expressed as a percentage of total GDP. We argue that trade can enhance the innovation level in a country by creating positive externalities which improve knowledge diffusion/flow. Furthermore, it increases the competition between the agents, hence the incentive, and at the final point it means to innovate (G. Grossman and Helpman, 1991; Roper et al., 2013; Papageorgiadis and Sharma, 2016; Akcigit et al., 2018).

5. *Natural resources rent*

We would like to examine if the abundance of the natural resources is a blessing or a curse for the nations’ innovation (Namazi and Mohammadi, 2018). We are expecting that countries with an abundance of natural resources are more likely to innovate for two reasons. Firstly, countries which heavily depend on natural resources tend to invest a fine proportion of their GDP in innovation because those countries understand both the finality of natural resources and the fact that, because of technological inventions, these natural resources might lose their use in the future. Secondly, as Sachs and Warner (2001) argued, the abundancy of natural resource could crowd-out the activities of the entrepreneurial which could lead to more innovation.

6. *GDP per Capita*

Bottazzi and Peri (2003), Furman et al. (2002) and Hu and Mathews (2005) had used this variable as independent in their research study, because it captures the ability of a country to translate its knowledge stock into a realised state of economic development. Furthermore, Paunov (2016) and Papageorgiadis and Sharma (2016) have used GDP per capita in the same context as we do, that of innovation, where they examined the relationship between GDP per capita and the innovation level. The World Bank calculates it by dividing the gross domestic product (GDP) by midyear population. We argue that the level of GDP per capita has an impact on the level of innovation outputs: lower level of GDP per capita reduces innovative outputs.

7. *The Worst Corruption Incidents (WCI)*

This variable is introduced by the author based on the CPI data mentioned above. This variable is a dummy variable which represents two subgroups of the sample: highly corrupted and less corrupted countries. WCI can take only two values: 1 or 0. Countries that score lower than 58 point, which is the mean of the corruption. less corrupt countries/clean countries, were assigned a value of 1, whilst countries with a corruption level higher than the mean (more corrupt countries) have a value of 0. This variable is mainly used in the dataset to explore the innovation level performance in the countries associated with a high level of corruption. Furthermore, this variable is meant to quantify the impact of corruption on the innovation level. Furthermore, this variable is included in all models to compare the level of innovation on less corrupt countries with more corrupt ones. The dummy variable is identified by corruption data compiled from the International Transparency Organization.

Dummy variable = WCI countries > mean (corruption) =1, otherwise 0.

3.6.2 The sample

The data which we are using to run the regression is an unbalanced panel dataset. It is unbalanced because the sources which we extracted the data from do not have the full dataset. The World Bank is the main source for the data in this paper, who have reported a number of reasons why data is not available for certain indicators for certain countries and certain years. Firstly, certain indicators are derived from sporadic surveys and are only available for some years. Secondly, certain data sets or indicators are only available from the year they were initiated. Thirdly, some countries do not regularly report data due to conflict, lack of statistical capacity or other reasons. Fourthly, certain countries do not have data for earlier years simply because they did not exist. Because we have missing observations for certain time periods of certain countries, we are using the annual data of 176 countries for the period of 2000–2017.

Table (3-1) shows a summary of the variables and the data source. Table (3-2) describes the summary statistics of the dependent variables and the explanatory variables which include their number of observations, mean, standard deviation, minimal value and maximum value. Table (3-3) shows the countries which are included in the regression and they are divided region-wise according to the World Bank division.

Table 3-1. The Glossary of Variables

Symbol of the Variables		Name of the Variable	Variable definition	Source of Data	Unit of Measurement
Dependent Variables	Rnd	Research & development	Research & development Expenditure	World bank	% of GDP
	Pat	Patents	The number of residential patents where the first-named applicant or assignee is a resident of the state or region concerned	World bank	Absolute number
	Researchers	Researchers	Number of Researchers and technicians working in the R&D Sector (per Million)	World bank	Absolute number
	Articles	Articles	number of scientific and engineering articles published in peer reviewed journals	World bank	Absolute number
Independent Variables	Corp	Corruption	Corruption Perception Index (0 indicates clean countries, 100 indicates corrupted countries)	Transparency International organization	Index
	Pop	Country Size (,000,000,000)	All the residents in the country regardless of legal status or citizenship	World bank	Absolute number
	Hc	Human Capital (,000,000)	Educational Attainment for Population Aged 25 and Over	Barro & Lee, 2013	Absolute number
	Capita	GDP per Capita (0,000)	GDP per capita is gross domestic product divided by midyear population.	World bank	US $
	Trade	Trade Openness	value of exports plus the value of imports (% of GDP)	World bank	% of GDP
	Nat	Natural Resources rent	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents (% of GDP)	World bank	% of GDP
	WCI	Worst Country Incidents	Dummy variable = WCI countries < mean (corruption) =1, otherwise 0		1,0

Table 3-2. Summary of the statistics results

Variables	Observations	Mean	Standard Deviation	Min	Max
Research & Development	3,168	0.410	0.784	0	4.405
Patents	3,168	0.6499	4.756	0	120.498
Researchers	3,168	0.677	1.475	0	8.255
Articles	3,168	0.807	3.607	0	44.023
Corruption	2,767	57.898	21.207	0	100
Country size (,000,000,000)	3,168	0.0384	0.1386	0	1.386
Human Capital (,000,000)	3,204	0.0190	0.0773	0	0.8721
GDP per Capita (0,000)	3,168	1.651	1.934	0	12.935
Trade Openness	3,168	83.666	56.877	0	442.62
Natural Resources Rent	3,168	7.949	12.142	0	82.529
Worst Country Incidents	3,204	0.322	0.468	0	1

Notes:
1) The summary of statistics is provided based on a time period from 2000 to 2017 for 176 countries worldwide.
2) The dataset used in this paper is unbalanced beca4se there are some gaps in year for some countries due to the unavailability of the data.

Table 3-3. List of countries included in this study

Europe & Central Asia	Sub-Saharan Africa	Latin America & Caribbean	East Asia & Pacific	Middle East & North Africa	South Asia	North America
Albania	Angola	Argentina	Australia	Algeria	Afghanistan	Canada
Armenia	Benin	Bahamas, The	Brunei Darussalam	Bahrain	Bangladesh	United States
Austria	Botswana	Barbados	Cambodia	Djibouti	Bhutan	
Azerbaijan	Burkina Faso	Bolivia	China	Egypt, Arab Rep.	India	
Belarus	Burundi	Brazil	Hong Kong SAR, China	Iran, Islamic Rep.	Maldives	
Belgium	Cabo Verde	Chile	Indonesia	Iraq	Nepal	
Bosnia and Herzegovina	Cameroon	Colombia	Japan	Israel	Pakistan	
Bulgaria	Central African Republic	Costa Rica	Korea, Rep.	Jordan	Sri Lanka	
Croatia	Chad	Cuba	Lao PDR	Kuwait		
Cyprus	Congo, Dem. Rep.	Dominica	Malaysia	Lebanon		
Czech Republic	Congo, Rep.	Dominican Republic	Mongolia	Libya		
Denmark	Cote d'Ivoire	Ecuador	Myanmar	Malta		
Estonia	Equatorial Guinea	El Salvador	New Zealand	Morocco		
Finland	Eritrea	Grenada	Papua New Guinea	Oman		
France	Ethiopia	Guatemala	Philippines	Qatar		
Georgia	Gabon	Guyana	Singapore	Saudi Arabia		
Germany	Gambia, The	Haiti	Solomon Islands	Syrian Arab Republic		
Greece	Ghana	Honduras	Thailand	Tunisia		
Hungary	Guinea	Jamaica	Timor-Leste	United Arab Emirates		
Iceland	Guinea-Bissau	Mexico	Vanuatu	Yemen, Rep.		
Ireland	Kenya	Nicaragua	Vietnam			
Italy	Lesotho	Panama				
Kazakhstan	Liberia	Paraguay				
Kosovo	Madagascar	Peru				
Kyrgyz Republic	Malawi	St. Lucia				
Latvia	Mali	St. Vincent and the Grenadines				
Lithuania	Mauritania	Suriname				
Luxembourg	Mauritius	Trinidad and Tobago				
Macedonia, FYR	Mozambique	Uruguay				
Moldova	Namibia	Venezuela, RB				
Montenegro	Niger					
Netherlands	Nigeria					
Norway	Rwanda					
Poland	Sao Tome and Principe					
Portugal	Senegal					
Romania	Seychelles					
Russian Federation	Sierra Leone					
Serbia	Somalia					
Slovak Republic	South Africa					
Slovenia	South Sudan					
Spain	Sudan					
Sweden	Tanzania					
Switzerland	Togo					
Tajikistan	Uganda					
Turkey	Zambia					
Turkmenistan	Zimbabwe					
Ukraine						
United Kingdom						
Uzbekistan						

3.6.3 Unit Root Test

The dataset which we are using is an unbalanced panel dataset. The appropriate unit root test to be used is the Fisher-type test because it does not require strongly balanced data and the individual's series can have gaps (Baltagi, 2008; p.244-245). Therefore, we are using the Fisher-type test (Fisher, 1932) using ADF and PP tests (Maddala and Wu, 1999; Choi, 2001). Furthermore, the lag lengths of the individual augmented Dicky-Fuller tests are allowed to differ. Fisher-type tests were used to test the null hypothesis which represents the presence of an "individual unit root". The Fisher-type test uses p-value from unit root tests for each country i. The test is asymptotically chi-square distributed with 2N degrees of freedom, $\boldsymbol{T_i} \rightarrow \infty$ $\boldsymbol{for\ finite\ N}$, (Nell and Zimmermann, 2011). The formula of the test is expressed as follows:

$$P = -2\sum_{i=1}^{N} ln\, p_i \qquad (3\text{-}15)$$

Furthermore, the results show that all variables are stationary. Table (3-4) shows the results of the unit root for all variables. It can be concluded from these results that the null hypothesis — the presence of an "individual unit root"— is strongly rejected. Thus, it can be assumed that all the series are stationary at the same level (no unit root).

Table 3-4. Unit Root Result

The variables	Individual intercept/trend/none	ADF- Fisher Chi Square			PP-Fisher Chi-Square		
		observations	cross sections	T-Stat	observations	cross sections	T-Stat
Patent	Individual effects	1893	117	416.388***	1989	117	431.167***
Research & Development	Individual effects	1944	118	441.403***	2006	118	510.108***
Researchers	Individual effects	1550	94	380.793***	1598	94	460.972***
Articles	Individual effects	2886	175	439.809***	2975	175	404.629**
Corruption	Individual effects	2500	176	465.298***	2561	176	488.143***
Trade Openness	Individual effects, individual linear trends	2832	173	465.865***	2941	173	387.625*
Natural Resources	None	2942	174	534.715***	2958	174	522.061***
Country Size	Individual effects, individual linear trends	2603	176	844.904***	2992	176	437.944***
Human Capital	Individual effects, individual linear trends	2213	140	315.458*	2380	140	43.767
GDP per Capita	Individual effects, individual linear trends	2799	173	441.263***	2941	173	443.293***
legend: * p<0.1;** p<0.05; *** p<0.01							
Ho: All panels contain unit roots							
Ha: At least one panel is stationary							

3.7 Empirical Results and Discussion

This section is divided into three sub-sections: the first presents the results on the national level for 176 countries over the period 2000-2017 of the innovation inputs, while the results of the innovation outputs are presented in the second sub-section, and are followed by the results of the seven regions comparison. The dependent variables have been illustrated against the main variable (i.e. corruption) using scatterplots to visually investigate the relationship between them.

3.7.1 Country Level

The histogram with kernel density, shown in Figure (3-4) has been illustrated by using CPI data from Transparency International. The mean of the CPI is 58, which is low, and indicates that most of the countries have a high level of corruption compared to the number of clean countries. During the study period, 31 countries from the sample were consistently clean, yet, 91 countries were corrupt, mainly from the sub-Saharan Region. The rest of the 54 countries were unstable between corruption and clean categories. Most of the clean countries (less corrupt) are located in the European Continent. On average, Denmark is considered to be the cleanest country in the world since 2000. Contrarily, Somalia is considered to be the most corrupt country with an average of 90 on the CPI index.

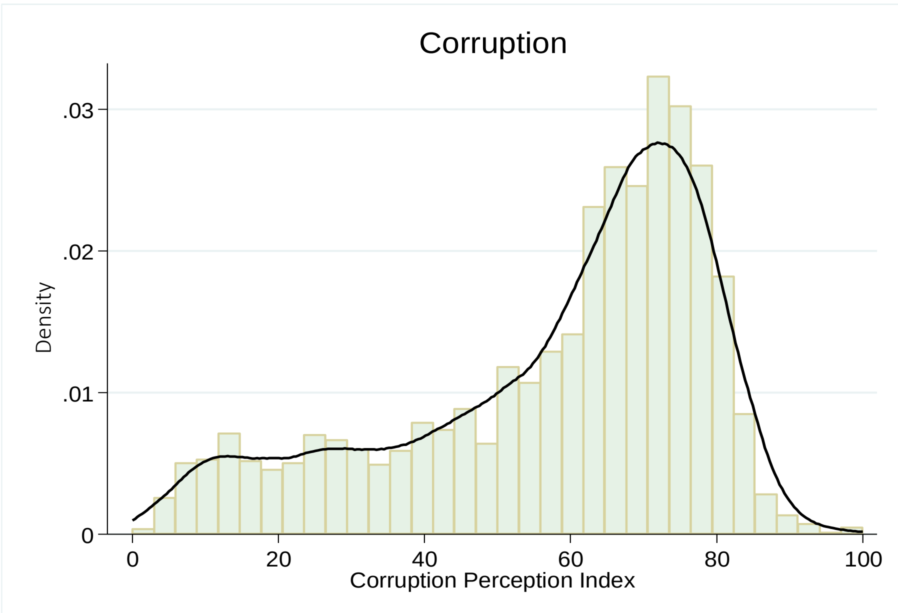

Figure 3-4. Average Corruption Distribution between Countries over the Period (2000-2017)

3.7.2 Innovation Inputs Results

The scatter plots shown in Figures (3-5) and (3-6) provide the relationship between innovation's input and corruption[27] based on the average values over the period (2000-2017), which indicates a negative association. This indicates that countries with higher levels of corruption are investing less in the R&D sector than those with lower levels of corruption (clean countries). Furthermore, the same association can be concluded from the number of researchers and corruption: countries with corruption activities tend to have fewer researchers working in the R&D sector compared to less corrupt countries (clean countries).

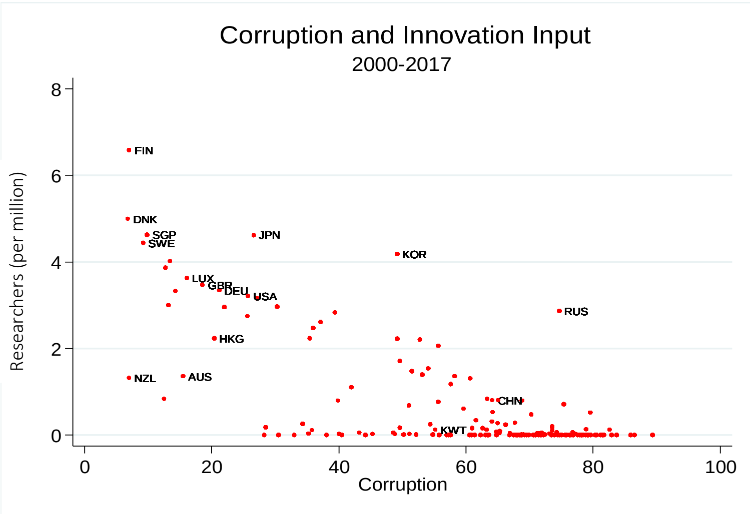

Figure 3-6. The relationship between corruption and research and number of researchers (Source: World Bank data)

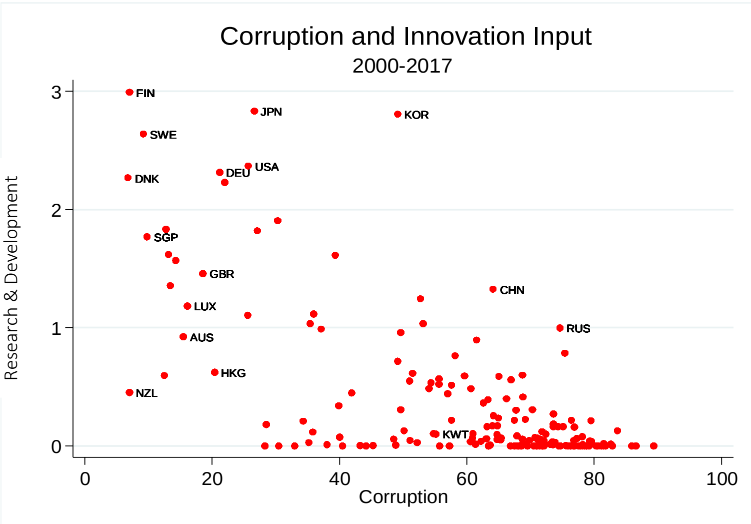

Figure 3-5. The relationship between level of corruption and research and development expenditures (Source: World Bank data)

[27] 0 indicates clean countries and 100 indicates corrupt countries.

According to the Hausman test and time-fixed effects test, the first two Models — (3-8) and (3-9) — in which the innovation input is the dependent variable, we conclude the fixed effects model to be the appropriate one as shown in Table (3-5). Additionally, Table (3-5) also shows the estimations of fixed effects of the determinants of innovation inputs. The main variable in this study is corruption, and our aim is to investigate its impact on innovation level, and it appears to be significant in some models.

Table 3-5. Fixed Effects estimates of Innovation inputs determinants

	Innovation Input	
	R&D	Researchers
	Fixed Effects	Fixed Effects
	Model (3-8)	Model (3-9)
Corruption[28]	-0.0056***	-0.00986*
	(-2.13)	(-1.77)
Country Size (,000,000,000)	-15.751***	-23.4858***
	(-4.16)	(-2.84)
Human Capital (,000,000)	26.9259***	43.9676***
	(4.14)	(2.67)
GDP per Capita	-0.1872***	-0.1089
	(-3.91)	(-1.35)
Trade Openness	0.0008	0.002147*
	(1.47)	(1.92)
Natural Resources[29]	0.0007	0.00077
	(0.7)	(0.45)
WCI	0.0231	0.0994
	(0.6)	(1.13)
Constant	1.1152***	1.349***
	(5.72)	(3.7)
t-statistics is reported in the parentheses ( ). Robust standard errors have been used.	legend: * p<0.1;** p<0.05; *** p<0.01	
Hausman Specification test of Random Effects	chi2 (6) ***	chi2(6)***
	154.960	92.15
Testing for time-fixed effects	4.88***	3.65***
	0.000	0.0000

[28] Corruption square is not added in the models, as the significant level is the same as corruption variable and the coefficients of corruption square is almost zero, therefore adding it in the models does not change the results.

[29]Natural resources rent: the results showed that this variable has no impact either positively or negatively on the level of innovation input, even though we expected a positive relationship. Nevertheless, we can conclude that depending on natural resources has nothing to do with the innovation level of nations.

The results of innovation input are expressed in Model (3-8) and Model (3-9) as shown in Table (3-5). The results of Model (3-8), where R&D is the dependent variable, reveal that corruption is negatively significant in that increasing 1 point in the corruption index leads the R&D expenditure to decrease by 0.0056 percentage points, which means that the countries with higher levels of corruption are less likely to invest in the R&D sector than less corrupt countries (clean countries). Sivak *et al.* (2011)[30], DiRienzo and Das (2015)[31] and Alam *et al.* (2019)[32] have supported the same results as the present study, yet with different controls. This result is consistent with the results shown in Figure (3-5) where the corruption level is negatively associated with R&D, meaning that countries with low levels of corruption (clean countries) are more likely to invest in R&D than countries with high levels of corruption. The results of Model (3-9), where the number of researchers is the dependent variable, are aligned with the results of the previous model. The findings from Model (3-9) show that corruption has a significant negative effect on the number of researchers — increasing one point in corruption index unit leads to a decrease in the number of researchers who are working in the R&D sector by 0.0105 researchers per million (10500 researchers) . Countries with a relatively high level of corruption are likely to have fewer researchers than countries with lower levels of corruption. Likewise, Figure (3-6) is consistent with our findings where corruption negatively associates to the number of researchers.

Based on the results of this paper, innovation inputs are significantly harmed by corruption. This negative impact can affect the economic growth of the nations through slowing down the technological advancement or innovation which is a main pillar of economic growth. The impact of corruption can be seen through the misallocation of resources (rising costs), namely that some resources are being paid into corrupt practices such as bribes and favoritism in order to overcome any bureaucratic issues. Vanishing corruption is challenging, therefore, we have to deal with it. To minimize the cost of corruption on innovation inputs and to enhance

[30] Sivak *et al.* (2011) conclude that corruption does affect innovation levels even though they focused on a smaller scale of countries.

[31] DiRienzo and Das (2015) used Global Innovation Index (GII, 2009) as innovation indicator and they suggest that corruption harms innovation activities across countries.

[32] Alam *et al.* (2019) used Generalized Method of Moments (GMM) estimation and their results are consistent with the current paper stating that corruption is detrimental on R&D investment.

innovation, the governments should deliberate policies and regulations to diminish this impact (DiRienzo and Das, 2015). Furthermore, other countries are fighting corruption through anti-corruption campaigns which mainly aims at making people aware of the shortfalls of the corruption at personal, societal, community and country level and most importantly, on the level of economic development and growth. China is a good example in adopting anti-corruption campaigns to fight corruption in the country (Gan and Xu, 2018). Xu and Yano (2017) and Gan and Xu (2018), empirically supported the positive impact of anti-corruption campaigns toward decreasing the effect of corruption, as they found that the Chinese provinces which have a strong anti-corruption campaigns are more likely to invest in innovation inputs. Furthermore, organizing corruption is a different concept which can be adopted, to minimize the impact of corruption and grease innovation to eventually help economic growth (Krammer, 2013). Therefore, to enhance innovation, resources (i.e. R&D and number of resources) must be allocated efficiently, and that will foster innovation and more generally grease the wheels of economic growth. It is worth mentioning that most of the literature that examines the relationship between innovation and corruption is at firms' level, and they show that corruption can grease innovation within firms[33]. When it comes to corruption at macro level, however, it shows a sanding effect on innovation.

Other variables which are included in our estimation have shown significant relationship with innovation inputs. Human capital is positively significant with innovation inputs: countries with educated people are more likely to invest in innovation inputs (Dakhli and De Clercq, 2004; Kato *et al.*, 2015). We can interpret the results by suggesting that when human capital increases by 1 million, the investment in the R&D sector increases by almost 27 percentage points and this does make sense as the innovation rises by human capital, so countries which focuse on improving the level and number of human capital by providing the proper education can improve their levels of innovation. In contrast to our argument, however, country size shows a significant negative relationship with the innovation input: when the country size increases by 1 billion, R&D expenditures decrease by 15.7 percentage points. This is because governments might focus on providing

[33] For more details see (Krastanova, 2014) and (Goel and Nelson, 2018).

educational, healthcare and infrastructural necessities to the people rather than focusing on the innovation sector. Even though, we have added this variable as an indication of the scale of workers that are potentially available for innovative activity. We can conclude that populated countries are both less likely to have people working in the R&D sector and to invest in the R&D sector. Our economy scale variable of GDP per capita shows significant negative relationship with the innovation input[34].When GDP per capita increases by 1 unit, the investment in the R&D sector decreases by 0.1872 percentage points. Natural resources is a main variable that we added in the models to examine its relationship with the innovation level, yet the results show no impact in all models. Although we argued that countries with an abundance of natural resources are more likely to innovate because those countries understand both the finality of natural resources and the usefulness of technological inventions. Furthermore, as Sachs and Warner (2001) argued, the abundancy of natural resources could crowd-out the activities of the entrepreneurial which could lead to more innovation. Yet the results allowed us to conclude that being rich in natural resources does not constitute an advantage but rather a difficulty precisely because countries that overly depend on natural resources in their economic growth are easier to corrupt (Ades and Di Tella, 1999; Gatti, 1999; Leite and Weidmann, 1999; Treisman, 2003; Lambsdorff, 2007; Goel and Nelson, 2010).

Trade openness and innovation inputs such as the number of researchers are likely to have a positive relationship: when the trade of a country increases by 1 percentage, the number of researchers increases by 214. Therefore, we can conclude that trade can enhance the innovation level in a country by creating positive externalities which improve knowledge diffusion/flow. Furthermore, it increases the competition between the agents, hence the incentive, and at the final point it leads to innovation (G. Grossman and Helpman, 1991; Roper et al., 2013; Papageorgiadis and Sharma, 2016; Akcigit et al., 2018). Those countries which trade more are less likely to be corrupted because those countries are exposed to international trade, which leaves little room for effective policy tools for policymakers to fight corruption. Additionally, when a country is more open to

[34] GDP per capita shows no significant in the number of researchers as indicated by Model (3-9).

trade, it means that this country has economic freedom as one of the determinants reducing corruption (Saha et al., 2009).

3.7.3 Innovation Outputs Results

The scatter plots shown in Figures (3-7) and (3-8) provide the relationship between innovation's output and corruption35 based on the average values over the period (2000-2017), which indicates that there is no clear relationship. For instance, China has the highest number of patents yet it is corrupt as shown in Figure (3-7). Furthermore, in terms of number of articles published, China shows the second highest level yet it is corrupt as shown in Figure (3-8).

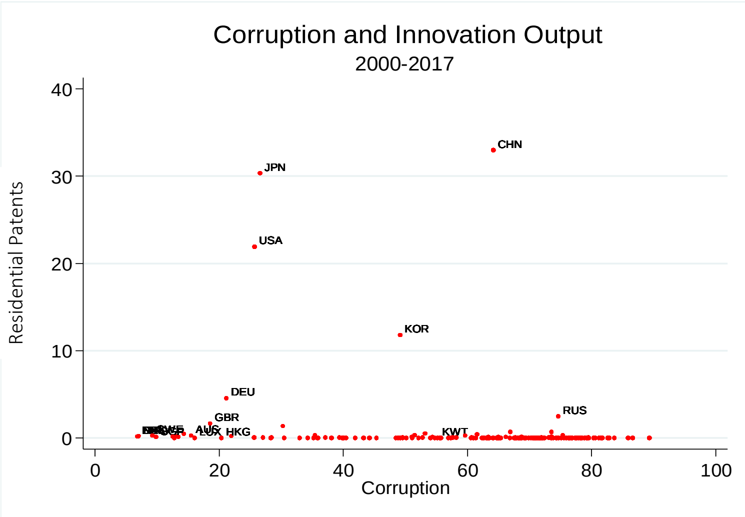

Figure 3-7. The relationship between the level of corruption and patents (Source: World Bank data)

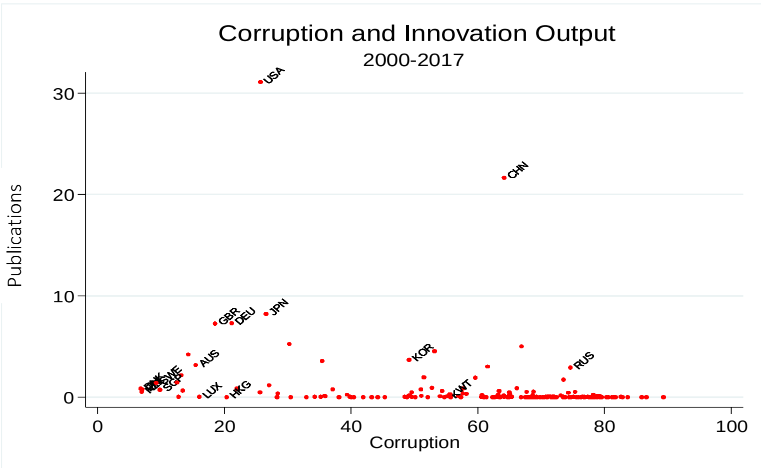

Figure 3-8.The relationship between the level of corruption and the number of articles (Source: World Bank data.)

[35] 0 indicates clean countries and 100 indicates corrupt countries.

According to the Hausman test and the time-fixed effects test, Models (3-10) and (3-11), in which the innovation output is the dependent variable, we conclude the random effects model to be the appropriate model as shown in the Table (3-6). Table (3-6) shows the estimations of the random effects of the determinants of innovation output. The main variable in this study is corruption, and our aim is to investigate its impact on innovation levels, and it appears to be significant in some models.

Table 3-6. Random Effects estimates of Innovation outputs determinants

	Innovation Output	
	Patents	Articles
	Random Effects	Random Effects
	Model (3-10)	Model (3-11)
Corruption	-0.0029 (-0.38)	0.0053 (0.51)
R&D	0.394 (0.85)	
Researchers	-0.134 (-1.54)	0.2712*** (3.3)
Articles	0.879* (1.89)	
Country Size (,000,000,000)	4.783 (0.88)	
GDP per Capita	-0.0553 (-0.78)	0.5686*** (2.28)
Natural Resources[36]	-0.0028 (-0.78)	-0.0019 (-0.73)
WCI	0.1376 (0.52)	-0.0488 (-0.26)
Constant	-0.1224 (-0.45)	-0.5810 (-0.79)
t-statistics is reported in the parentheses ( ). Robust standard errors have been used.	legend: * p<0.1;** p<0.05; *** p<0.01	
Hausman Specification test of Random Effects	chi2(8)***	chi2(5)***
	25.29	26.04
Testing for time-fixed effects	1.25	1.51
	0.2323	0.0953

[36]Natural resources rent: the results showed that this variable has no impact either positively or negatively on the level of innovation output. Although we expected a positive relationship, we can conclude that depending on natural resources does not impact the innovation level of nations.

The results of innovation outputs are represented in Model (3-10) and Model (3-11) that show divergence from the results of innovation inputs. However, the results of Model (3-10), where the number of patents is the dependent variable, although do not indicate that corruption might significantly affect the number of patents, the sign is consistent with the previous models' negative sign. This result explains the data in Figure (3-7), which we found difficult to interpret because of the unclear relationship between corruption and residential patents. We cannot, in this way, conclude that the number of patents can be harmed by the corruption level across countries. Corruption levels, in fact, seem to be unrelated to patents (Varsakelis, 2006). Finally, in Model (3-11), where the number of articles is the dependent variable, the same conclusion is found: the results show that corruption has no impact on the number of articles. We can thus suggest that corruption has no impact on the number of articles published. In brief, we can conclude that corruption level has no impact on innovation output. Mahagaonkar (2008), empirically shows that corruption plays a inhibitory role rather than facilitating innovation products – with articles and patents considered as products or outputs of innovation – similarly to the opinions of Anokhin and Schulze (2009), Q. Huang and Yuan (2016) and Xu and Yano (2017). Rather differently, Lau *et al.* (2015) and Xie *et al.*(2018) have found that corruption can be facilitative rather than inhibit5ng towards innovation outputs.

Nonetheless, other variables included in our models are significant. Articles as explanatory variables in a number of patent models show significant positive relationship. Furthermore, GDP per capita which is the economy scale in our model shows a positively significant relationship with innovation outputs namely number of articles: when the GDP per capita[37] increases by 10,000 US dollars, the number of articles published increases by 0.5686 articles. Countries with a high level of GDP per capita publishes more articles than countries with lower GDP per capita, but this is in conflict with the results found by Hu and Mathews (2005). Our results suggest that country size is unconnected with innovation outputs (Anokhin and Schulze, 2009).

[37] GDP per Capita is in US dollar (PPP, constant at 2011 prices), where we have rescaled all data by dividing them by 10,000.

In summary, our findings indicate that global corruption is more detrimental to global innovation inputs rather than being a rent seeking, while we find no stifling effect on global innovation outputs. Our findings also point out that highly populated countries are less likely to invest in the innovation sector (R&D). At the same time, however, human capital size shows a positive impact on innovation inputs in that countries with more educated people are more likely to have them work as researchers. It was possible to conclude from our findings that it is unnecessary to be innovative for those countries that are blessed with natural resources, yet those resources could be a curse because the country becomes more likely to be corrupt. GDP per capita, our economy scale variable shows that wealthy countries are less likely to invest in the innovation sector, yet they are more likely to publish papers, which might be because they tend to publish in local journals instead of high ranking international journals. Furthermore, countries with more researchers are more likely to publish. These corrupt practices are generally considered to be detrimental to the economic growth of a country, and innovation is a main pillar in the economic growth model.

3.7.4 The Seven Regions

The plot in Figure (3-9) is based on World Bank data, and it shows that the regions are scattered in terms of the relationship between innovation and corruption. As shown in the figure, the sub-Saharan region has the most corrupt countries, while North America is considered to be the cleanest region among others. We think, however, that we cannot consider North America to be the cleanest region because it includes only two countries, namely the USA and Canada. Regions consisting of countries with low levels of corruption such as Europe and Central Asia are more likely to spend more on the R&D sector than countries which have high levels of corruption such as the Middle East and Northern Africa.

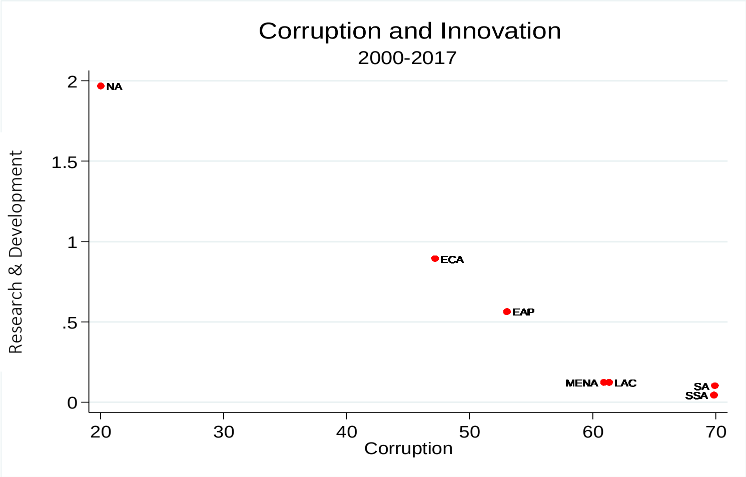

Figure 3-9. The relationship between corruption and innovation region-wise.
Source: World Bank data

Using data from the World Bank, Figure (3-10) shows the distribution of the European and Central Asian countries. This is a heterogeneous region because it includes the cleanest countries and some corrupt ones. It can be observed that the Netherlands, Switzerland, Norway, Denmark and Finland are clustered almost on the same area of the figure (even though it might be because of the spillover effect of innovation, which will be analysed in a later study). Albania is situated at the bottom of the figure, suggesting both that the government does not invest in R&D and that the country is quite corrupt.

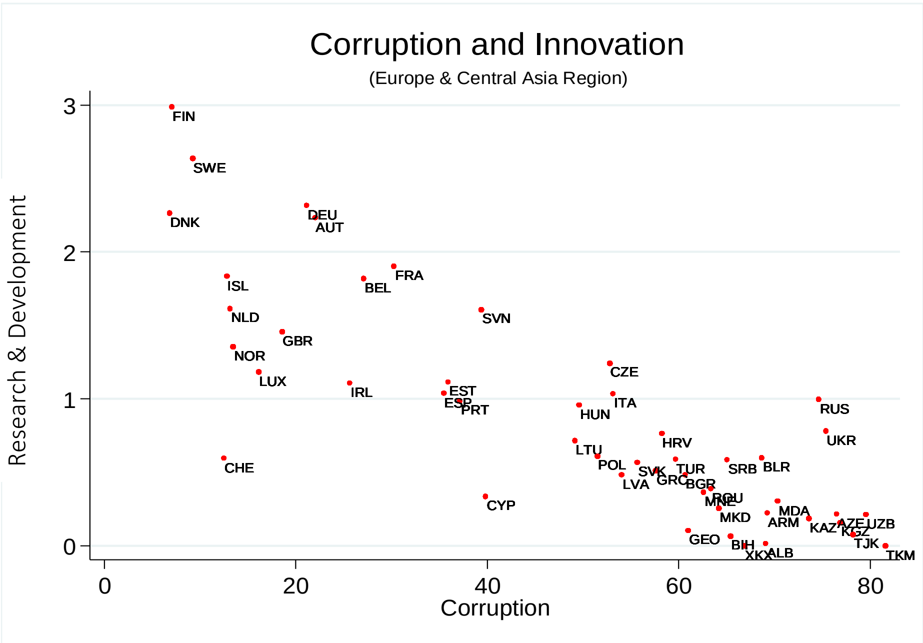

Figure 3-10. Relationship between corruption and innovation in Europe and Central Asia
Source: World Bank Data

After running the regressions for the 7 regions using the suggested models, the results for innovation inputs are shown in Tables (3-7) and (3-8). In regard to the results of innovation output, these are shown in Tables (3-9) and (3-10). However, the results vary from one region to another due to geographical and cultural characteristics, language, and regional characteristics. Corruption, which is our main variable, has a diverse relationship with the innovation proxies which we are using in this paper. Most current studies examine different divisions of regions, such as Eastern Europe and Central Asia (Habiyaremye and Raymond, 2018), the African region (Oluwatobi et al., 2015) and OECD countries (Salinas-Jimenez and Salinas-Jimenez, 2006). Other research projects focus on one country only (Gan and Xu, 2018). The current project, however, is distinct in that it uses the World Bank division of regions.

Referring to our first and second models where innovation inputs — R&D and the number of researchers — are the dependent variables, Tables (3-7) and (3-8) show the results of the seven regions. East Asia & Pacific (EAP) is the only region which shows that corruption is detrimental to the innovation inputs: when corruption increases by 1 point in the scale, investing in the R&D decreases by 0.016 percentage points and the number of researchers decreases by 0.0423 researchers per million. Similarly to this, Habiyaremye and Raymond (2018) also empirically found that corruption stifles R&D activities in Eastern Europe and Central Asia. Furthermore, WCI, the dummy variable, for corrupt countries shows dissimilar results in the EAP region and SSA region; the EAP region shows a negative significant association with the innovation inputs such as R&D, and this is because most of the countries in this region are less corrupt. The joint negative significant relationship between corruption and the WCI dummy variable with innovation inputs points to the fact that corruption harms innovation in developed countries. In contrast, WCI shows a positive significant impact on innovation inputs —R&D and researchers— in the SSA region. This relationship suggests that corruption can grease innovation inputs by investing more both in R&D and researchers. We can argue, however, that those resources — innovation inputs — can be used in corrupt practices in that unreal researchers might be the reason behind this positive association. The amount of R&D and researchers are only recorded in governmental records with no sensed outcome – and those resources go to the benefit of a few people rather than the common good. Furthermore, it might be possible that corruption is a tax on the inputs, just as it is a tax on other activities. Hence, this should not necessarily be interpreted as a corruption boosting innovation. Rather, corruption adds to the cost of doing research and development, which is definitely inadvisable. Most of the SSA region depends on natural resources and a fine proportion goes to innovation inputs as shown in Table (3-7). Wealthy yet less developed countries in the SSA can make use of corruption in order to augment innovation, consequently, the economic growth of those countries can accelerate. However, in regard to the rest of the regions included in this study, the results of corruption show no significant relationship to innovation inputs.

Based on the results in Tables (3-7) and (3-8) where natural resources are unrelated to the innovation inputs, the results in the regions show that wealthy countries that depend on natural resources or have an abundance of natural resources are located in the MENA, NA, SA and SSA regions and invest a fine proportion in the R&D sector. Furthermore, wealthy countries that are located in the LAC, MENA, and NA regions have a higher number of researchers than those which have less abundance of natural resources. Consequently, we can argue that wealthy countries seek to match developed countries by investing in innovation inputs because they know that technological advancement is the future. We can also argue that those inputs might be spent in corrupt activities through a misallocation of resources (Acemoglu and Verdier, 2000) because we cannot see any tangible results of those resources.

Also, the results indicate that country size is negatively significant with innovation inputs in some of the regions as presented in the Tables (3-7) and (3-8). Indeed, innovation has a direct positive effect coming from the human capital size for almost all regions except the MENA region, where it shows a negative relationship in that 1,000,000 human capital can result in a decrease of circa 10 percentage points in innovation inputs (R&D). As all countries in the MENA region are developing countries with young generations, the governments focus on building the human capital (education) rather than spending in the innovation sector (R&D).

Table 3-7. Fixed Effects estimates of Innovation Inputs- Research & Development- Regions

Innovation Inputs/ Research & Development

	EAP	ECA	LAC	MENA	NA	SA	SSA
Corruption	-0.016*	-0.0085	-0.00064	0.0048	0.0183	0.00157	-0.0017
Country Size (,000,000,000)	-9.989	-23.671*	-46.0424***	7.033	7.6375	-9.978***	0.630
Human Capital (,000,000)	21.464**	78.790***	60.070***	-10.131*	24.415*	14.1695***	-19.31
GDP per Capita	-.2679***	-.26291***	0.0107	-0.0701	-1.451	-0.0193	-0.1384
Trade Openness	0.0030*	0.00061	0.00077	0.0022	0.01697	-0.0011	-0.00
Natural Resources	0.0034	-0.0011	0.000999	0.0013***	0.256***	0.01895*	0.00113*
WCI	-.3874***	0.0145	-0.0622	-0.1169	(omitted)	(omitted)	.0665**
Constant	1.614***	1.517***	.50805**	0.0423	3.0062	.8938***	.23**

legend: * p<0.1;** p<0.05; *** p<0.01

Table 3-8. Fixed Effects estimates of Innovation Inputs- Number of Researchers- Regions

Innovation Inputs/ Researchers

	EAP	ECA	LAC	MENA	NA	SA	SSA
Corruption	-0.0423**	-0.0150	-0.00066	0.0203	-0.0347	0.0000034	-0.00055
Country Size (,000,000,000)	-19.959	-36.954	-44.254***	-0.775	21.307**	0.595	-0.0683
Human Capital (,000,000)	28.991	140.999***	50.294***	37.599	81.523*	-0.888	-3.558
GDP per Capita	-0.244	-0.0336	.115**	0.0258	-2.326	-0.0292	0.0164
Natural Resources	0.006	0.0134	0.00099*	0.0033*	0.6281***	0.00083187	0.00014
WCI	-0.768	0.0753	-0.0023	0.180	(omitted)	(omitted)	0.0389*
Constant	4.624***	1.643*	.429**	-1.529	1.025	-0.0130	0.0275

legend: * p<0.1;** p<0.05; *** p<0.01

Based on our third and fourth models where innovation outputs such as patents and articles are the dependent variables, Table (3-9) and (3-10) show the results of the seven regions. The SSA region has a significant positive relationship with the innovation outputs: when the corruption increases by 1 point in the scale, the number of residential patents in SSA region increases by 0.00018 patents and this amount is almost 0. Consequently, corruption shows an unreal greasing effect on innovation output in the SSA region, and, as mentioned previously based on TI data, the SSA region involves the most corrupt countries. Drawing on empirical evidence by Oluwatobi et al. (2015) we argue in this paper that controlling corruption that results in a fall in corruption can help innovation to flourish.

Table 3-9. Random Effects estimates of Innovation Outputs- Number of Patents-Regions

Innovation Outputs/ Patents

	EAP	ECA	LAC	MENA	NA	SA	SSA
Corruption	0.0619	-0.0028	-0.0005	0.0012	0.0122	0.00028	.00018**
Country Size (,000,000,000)	-4.539	14.711***	.7291*	0.549	60.663***	.09487***	-0.0536
R&D	-1.249	0.118*	0.0532	-.01196**	1.756**	.12108***	0.00499
Researchers	1.075	-0.0226	-0.0029	-0.0043	-0.641	-0.254*	0.0121
Articles	1.920***	.0584***	.05799***	.26911***	.312***	.10829***	.08513***
GDP per Capita	-0.148	-0.058	-0.0045	0.00075	-6.831	0.0061	-0.00051
Natural Resources	-0.1034	0.0036	0.00	0.00039	-0.498	-0.0128*	-0.00
WCI	-2.268	0.0192	0.0099	-0.0159	(omitted)	-0.0583*	-0.0096
Constant	-0.845	0.1539	0.0165	-0.0941	25.87	0.0315	-0.00327

legend: * p<0.1;** p<0.05; *** p<0.01

Table 3-10. Random Effects estimates of Innovation Outputs- Number of Articles Published-Regions

Innovation Outputs/ Articles

	EAP	ECA	LAC	MENA	NA	SA	SSA
Corruption	-0.042	0.019	0.0128	0.0048	0.8218*	-0.0898	-0.00052
GDP per Capita	1.079	.619***	0.368	0.0142	25.015***	0.8545	0.0287
Researchers	0.366*	.2009**	-0.331	.0587***	2.378***	3.425	.4013**
Natural Resources	0.038	0.0047	0.0045	0.00	1.550	.5236***	-0.000199
WCI	2.38	-0.1996	-0.393	-0.0483	(omitted)	5.186	-0.000135
Constant	-0.081	-1.761	-0.728	-0.0622	-123.417***	1.136	0.0502

legend: * p<0.1;** p<0.05; *** p<0.01

In summary, corruption has a negative effect on the innovation inputs of R&D and researchers in the EAP region, yet has no effect on the rest of the regions included in this study. Furthermore, WCI shows divergent results for the EAP region and the SSA region. WCI has a negative significant relationship with the innovation inputs in the EAP region, yet a positive significant relationship in the SSA region. The joint negative relationship in the EAP region points to the argument that corruption is detrimental to innovation in developed countries. The positive relationship in the SSA region reveals, however, that corruption can spur innovation inputs in poor countries. In addition, corruption statistically showed a significant positive impact on the innovation outputs (patents), thus we can argue that some corruption in poor countries can be useful to overcome any bureaucratic issues. We can also argue that the resources of innovation inputs are being spent in corruption activities because we cannot sense any results of these. Significantly, therefore, the misallocation of resources can harm innovation, and this means that the answer to the study's main question is yes: corruption is detrimental to innovation.

The relationship between corruption and innovation has a received a lot of attention by researchers in the field of economics . This study provides novel insights into this relationship at macro-level, and it contributes to the empirical literature of innovation and corruption, by providing a cross country empirical analysis of how corruption distresses innovation activities. Furthermore, this paper adds to the strand of the literature by means of employing four proxies of innovation input and output. Using four proxies is expected to yield consistent and valid results and that is what we have received in this paper: corruption is indeed detrimental to innovation input for both measurements and it clearly has no impact on innovation output for both measurements.

3.8 Conclusion

This study answered its main question, which enquires "is corruption detrimental to innovation?" The empirical evidence reveals that there is a significant adverse impact of corruption on innovation activities representing in innovation input. This impact is harming a nation's ability to innovate through the misallocation of resources that raises costs and impairs trust (Acemoglu and Verdier, 2000; DiRienzo and Das, 2015) and thus, eventually, deters economic growth. On the other hand, corruption shows no impact on innovation output. Regarding the comparison between regions, the corruption in the EAP region has a negative effect on the innovation inputs of R&D and researchers. In contrast to this, corruption is positively significant to the innovation inputs of R&D and researchers in the SSA region. It seems, therefore, that corruption greases innovation inputs. However, this result should not necessarily be interpreted as a corruption boosting innovation because this positive impact is merely due to corruption being a tax on the inputs just as on another activity. Rather, by adding to its cost, corruption has a negative effect on research and development. In the same region, although corruption has a positive impact on innovation outputs (the number of patents) because the impact is economically insignificant, it is difficult to call it reliable and suggest that corruption greases innovation. Therefore, it is possible that, similarly to national level results, corruption has no impact on innovation outputs. In light of these results, the conclusion remains that in general, corruption is detrimental to innovation.

In accordance with the empirical evidence, we suggest certain policy implications as follows. Firstly, due to the misallocation of resources, governments/policymakers must focus on anti-corruption campaigns which have shown their effectiveness in reducing corruption (Dang and Yang, 2016; Xu and Yano, 2017; Gan and Xu, 2018). Secondly, governments shall consider putting some policies in order to trigger innovation activities such as eliminating unnecessary bureaucratic and red tape barriers. Thirdly, policymakers are urged to undertake serious measures to spur innovative activities by eliminating the unnecessary bureaucratic matters which are the main reason of corruption and which lead to hindering both economic growth and innovation. Fourthly, we recommend encouraging innovation-friendly procedures by enforcing the e-government services designed to reduce the time spent in the governmental procedures and eliminate unnecessary intermediaries and induce a fair access to information and services. All these measures can eventually help a country to innovate more and thus potentially allow the global innovation to flourish.

3.9 Limitations and Future Research Directions

Some of the findings in this research project are unique to the literature, while others shed additional light on previous results due to working with a larger sample of countries. While this work provides some interesting insights and ideas for future work in the strain, it has some limitations. One limitation is, and this is common in quantitative studies using real data for cross-country analyses of corruption, innovation and economic indicators: in our paper case we used unbalanced panel data most likely containing measurement errors. As with all cross-country studies exploring such country factors, the results presented here are limited to the quality of these data measures, which are imperfect. Therefore, it will be necessary to use more accurate, better quality, more reliable and easier access data for further robust examination. For robustness, it would be worthwhile to try other measures of innovation inputs and outputs drawing on Cirera and Maloney (2017) or use the Global Innovation Index (GII) considered to be another proxy for global innovation. More interestingly, it would be of relevance to combine corruption with policies and regulations. For the robustness of results, an anti-corruption index might be used to check with it the current results consistence.

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This declaration concerns the article entitled:									
Does Contagious Corruption Affects Home innovation?									
Publication status (tick one)									
Draft manuscript	X	**Submitted**		**In review**		**Accepted**		**Published**	
Publication details (reference)									
Copyright status (tick the appropriate statement)									
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Statement from Candidate	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.								
Signed	**Maryam Al-Bulushi**				**Date**	**31/07/2019**			

4. Chapter Four: Does Contagious Corruption Affects Home Innovation?

4.1 Abstract

Corruption can be contagious and innovation can spillover, therefore, this paper investigates the effect of neighbouring corruption on home country innovation by using Two Stages Least Squares (2SLS) method. Furthermore, random effects technique is used to address if the neighbouring innovation has an impact on the home corruption. The empirical evidence reveals that neighbouring corruption negatively affects home innovation, as well as being adversely affected by neighbouring innovation. Moreover, geographical proximity of corrupted countries can lead to worsen corruption levels in both (home and neighbouring). In conclusion, countries can be affected corresponding to their neighbours, which can be challenging to overcome as such proximity cannot be changed. However, governments should strain to enforce laws and regulation to fight corruption spillage over the borders. Additionally, anti-corruption campaigns can be established in the home country to tumble corruption in home country, subsequently tumbling corruption in the neighbouring country.

Keywords: Neighbouring Corruption, Neighbouring Innovation, Geographical Proximity, Economic Openness.

4.2 Introduction

Countries with common borders usually have similar economic, political and cultural characteristics (Becker et al., 2009), linguistic similarities (Helliwell, 1997), shared histories and culture (Anselin, 1988; Herwartz et al., 2011). Consequently, corruption in the home country cannot be isolated from corruption in neighbouring countries, which is an issue that many recent studies attempt to explore. However, many researchers claim that corruption within a country is largely dependent on the corruption with its neighbouring countries (Goel and Nelson, 2007; Becker et al., 2009; Lee and Guven, 2013; Feng et al., 2018; Sui et al., 2018). These researchers found that corruption is contagious: corruption in one place, country, and state inevitably influences corruption in a neighbouring place, country, and states. However, one of the reasons behind the spreading of this infection among neighbour countries is that those countries show an imitation behavior for corruption (Fichtlscherer et al., 2010; Accinelli and Carrera, 2012).

Besides investigating the existence of corruption as a contagion phenomenon, some researchers extend the contagious corruption perspective by considering the influence of corruption between the host country and its surrounding countries. According to the literature, corruption can spillover from neighbouring countries to the home country through two main determinates or channels, which are economic openness and geographical proximity. Economic Openness is related to trade flow and foreign direct investment, including inflow and outflow (Ades and Di Tella, 1999; Wei, 2000; Gokcekus and Knörich, 2006; O'Trakoun, 2017). On the other hand, geographical proximity is associated with the common border neighbors and the distance between cities (Goel and Nelson, 2007; Becker et al., 2009; Quazi et al., 2013; Goel and Saunoris, 2014; O'Trakoun, 2017; Feng et al., 2018; Sui et al., 2018). Additionally, some researchers like Becker et al. (2009) who argued that corruption could contagious or travel from a place to another because of the common culture.

Although in our previous study —Chapter 3 of this thesis, entitled "Is corruption detrimental to Innovation?—we have shown that corruption in the home country has a significant effect on the innovation level, it is worth extending that study through including the influence of other factors such as neighbours' corruption. According to the literature, as mentioned earlier, these factors have a strong influence on home corruption. Because, to the best of our knowledge, it has not been addressed, this paper provides an empirical study to examine the influence of neighbouring corruption on home innovation. This is important because innovation is the main pillar of the nation's economic growth, and it might lead to slowing the economic growth of the home country. Moreover, the impact of neighbouring innovation on the home country corruption is also considered.

We believe that previous studies neglect the phenomenon that neighbouring corruption might infect home innovation, which leads to slowing the economic growth of the home country. Therefore, this paper aims to fill this gap by providing empirical evidence on whether contagious corruption affects home country innovation. In sum, this study seeks to investigate two main issues: 1) examining the impact of neighbouring countries' corruption on home innovation, and 2) examining the impact of neighbouring countries' innovation on home corruption. According to the Durbin-Wu-Hausman test, we use the Two Stages Least Squares (2SLS) technique to address the first issue as it solves the problem of endogeneity by correcting the problem of an endogenous variable by adding instrumental variable—. Regarding the second objective in this study, according to the Hausman test result, the random effects model is appropriate to investigate. Hence, we used a data set of 140 countries over 15 years and assumed that the input variables for the home country are determined from the average values of the neighbouring countries. This study presents new evidence which shows that home innovation can be harmed terribly because of being a neighbour of corrupted countries and thus have its economic growth slowing down . Furthermore, when the neighbouring countries focus on the innovation in their country, that can help in reducing corruption at the home country (Johari and Ibrahim, 2017).

This paper has several unique and novel elements compared to the extant work in this area as it carries three unique contributions to the literature. Firstly, to the best of our knowledge and while the past literature focused on studying the corruption contagious on home corruption, this study focuses on investigating the spillover impact of neighbouring country corruption on home country innovation — how much the neighbour corruption will affect the home country in terms of innovation—. Secondly, we are examining for 140 countries over the period 2003-2017, which is different from studies conducted by either Becker et al. (2009) who used cross-sectional data for 123 countries or Goel and Nelson (2007) who focused only on US states. Finally, we believe that our findings offer a significant contribution to academia in the field of corruption and innovation literature.

After this brief introduction, the next section discusses theoretical and empirical previous studies on the corruption infectivity. Section 4 explains the methodology used in this paper and is followed by the description of the data and variables construction for this study in section 5. Section 6 provides a comprehensive interpretation and analysis of the results along with discussion. Lastly, section 7 provides the conclusion of the paper. Finally, the limitations of the research and avenues for future work are drawn in section 8.

4.3 Literature Review

Corruption is one of the most challenging obstructs to economic growth and Transparency International (TI), which is the global civil society organisation leading the fight against corruption and the organisation responsible for collecting corruption data, has defined it as the abuse of entrusted power for private gain. Although it happens behind closed doors (underneath tables); yet the results of corruption can be sensed/seen. Corruption can affect economic growth through several means, and innovation is one of these. Thus, there is vast literature on corruption and its impact on economic growth at macro-level (Mo, 2001; Bentzen, 2012; Dridi, 2013; Dutta and Sobel, 2016) and micro-level (Fisman and Svensson, 2007; De Rosa et al., 2010).The relationship between corruption and economic growth has been well established, as stated by the sanding and greasing hypothesis. Aside from this, there is a considerable amount of literature on the relationship between corruption and innovation on micro level (de Waldemar, 2012; Smith et al., 2014; Nguyen et al., 2016; Habiyaremye and Raymond, 2018) and also on macro level (Anokhin and Schulze, 2009; DiRienzo and Das, 2015; Johari and Ibrahim, 2017).

Consequently, corruption plays a major role in the economic growth of the home country because innovation is the main pillar of the nation's economic growth, and it might result in slowing down this growth. Corruption is considered as a global trend in which its destruction can exceed the home country, yet it can cross boundaries of the home country and reach neighbour countries and vice versa. This means that corruption can spillover between firms which can reach between countries, and it can also be regionalised (Sui et al., 2018). Therefore, recent literature consistently points out that corruption is not only a problem of an individual country, but it is also a common phenomenon that may spread across most of the developing countries, especially in the era of globalization when interactions between countries have been increasing and forming a bridge for the contagion of corruption (Attila, 2008). Furthermore, several studies have offered a consistent view regarding this phenomena, such as Attila (2008) and Becker et al. (2009), who discover that countries with frequent economic trade might be more easily affected by the diffusion of corruption, whereas those with similar economic, political and institutional environment might be more susceptible to the spreading of corruption.

The literature on contagious corruption is scarce because it was established recently. However, the idea of corruption being contiguous started from the study carried out by Goel and Nelson (2007) who used US States data and empirically demonstrated that an increase in neighbouring corruption of states results in increasing the convections within the state. They concluded that corruption is contagious within US states. Then, Attila (2008) who uses cross-sectional data over the period 1996-2002 and Becker et al. (2009) who uses the cross-sectional analysis of 123 countries both provide empirical evidence at the country level that corruption is contagious among countries. Hence, a higher level of perceived corruption in adjacent economies leads to a domestic increase in perceived corruption. Also, Quazi et al. (2013) presented consistent results with the previous studies in which corruption is contagious when they used 16 countries from the South and East Asia regions. Moreover, in a recent study, O'Trakoun (2017) has shown that corruption in neighbouring countries can have adverse contagion effect on the domestic economy. Also, Sui et al. (2018) provide empirical evidence not only to confirm contagious corruption through geographical distance, but also that corruption can spread even to countries that have similar levels of GDP per capita. However, the previous evidence regarding the idea that corruption is contagious contradicts the outcomes of the study presented by Márquez et al. (2011) who examined the same theory (hypothesis) of detecting if corruption is contagious or not using spatial econometrics techniques. Márquez *et al*. found that neighbouring countries tend to show similar levels of corruption because they face similar characteristics and similar institutional environments. Based on the above literature, we can conclude that corruption is indeed contagious, and isolating the countries from this infection is not an individual responsibility, yet it is everyone's responsibility.

According to previous literature, Sui et al. (2018) have summarised and presented several reasons that assist corruption to spillover/ or spread among people, agents, states and countries. First, learning and peer-group behaviour can lead to the dispersal of corruption in countries that have numerous contacts in business (Kaymak and Bektas, 2015). Second, neighbouring countries with similarities in economic development tend to imitate corrupt behaviour from next door, which points to a demonstration effect of corruption (Accinelli and Carrera, 2012). Third, the availability of international platforms for exchanging information and experiences can promote the fast diffusion of corruption among countries using these platforms. Among these are the World Bank and the Organization for Economic Co-operation and Development (OECD) (Becker et al., 2009). Fourth, the transfer of illegal assets by some officials away from their countries to other places will transfer corruption as well. This is due to the increased awareness of personal corruption and the sensibility of asset protection (Attila, 2008).

Past studies that focused on examining the spillover of corruption from a country to another, divided the determinants or channels in which corruption can be a spillover into two main categories: 1) economic openness; and 2) geographical proximity. Economic openness can be considered as a constraint to corruption through trade as well as-by altering economic incentives — due to the cost-benefits balance changes; and they concluded that openness could help to reduce the corruption in the country (Ades and Di Tella, 1999; Wei, 2000; Gokcekus and Knörich, 2006; O'Trakoun, 2017). However, the main difference between other studies and our study is that we argue that the openness of the neighbouring countries can be inversely related to the home country innovation via reducing the home country corruption while other studies focused on investigating the impact of the openness of the same country rather than focusing on the neighbouring countries. We argue, furthermore, that economic openness to other countries can help the spillover to take place. The two main variables we are using and indicating to economic openness in this study are trade and foreign direct investment-outflow.

As mentioned before, early geographical proximity is one of the main channels that corruption can spillover from the neighbouring countries to impair innovation at the home country. Many researchers have argued that corruption can travel from the neighbouring countries to the home country through this channel. Thus, it has been used by many researchers through different measurements, i.e. distance and common borders are two determinants for geographical proximity and have been widely used in the literature (Goel and Nelson, 2007; Becker et al., 2009; Quazi et al., 2013; Goel and Saunoris, 2014; O'Trakoun, 2017; Feng et al., 2018; Sui et al., 2018). Thus, in this study, we are using three different measurements for geographical proximity, namely, geographical closeness between capital cities, the number of neighbours, and being a landlocked country. The main difference between other related studies and our study is that we are investigating if the neighbouring corruption can affect the level of innovation of the home country due to geographical proximity.

In summary, we believe that previous studies focused on examining corruption spill-over from a country to another —being contagious— (Goel and Nelson, 2007; Attila, 2008; Becker et al., 2009; Lopez-Valcarcel et al., 2017; Feng et al., 2018; Sui et al., 2018), yet they neglected that this contagious corruption can infect the innovation at home country. Therefore, we are considering contagious corruption as a potential channel in which this infection can spillover, harming home innovation. Thus, ignoring the contagion phenomenon can have severe consequences on the economic growth of countries and can eventually slow economic growth. Overall, to the best of our knowledge, no one has investigated the impact of neighbouring corruption on innovation at home country. Although all previous studies have investigated if corruption is contagious or not, in our project we present a different view where we are quantifying the impact of the contagious effect on the home country innovation.

4.4 Methodology

We carry out an analysis to investigate the spillover effects of neighbouring countries corruption to home country innovation. Furthermore, we are investigating the spillover effects of neighbouring countries innovation on home country corruption. Therefore, in order to address these issues, we consider other variables which might influence corruption and innovation together with our main variables of corruption and innovation in this paper. Hence, we use unbalanced panel data for 140 countries over the period (2003-2017).

The general panel model is given by equation (4-1).

$$Y_{it} = \alpha_i + \beta X_{it} + \mu_{it} \qquad (4\text{-}1)$$

where, Y signifies home innovation level, represented by R&D and in the Model (4-1), and Y refers to the corruption level of the home country. X is a vector that represents our main variables of the two models: average corruption of the neighbouring countries, and average innovation of the neighbouring countries, respectively. Furthermore, it represents other exogenous variables which are: geographical closeness, average trade of the neighbouring countries, average foreign direct investment-outflow of the neighbouring countries, land lock dummy, natural resources, a log of gross domestic product, year effects dummy and the neighbour's dummies[38]. In this study, there are two models to be estimated in the (4-2) and (4-3) models, which are given as follows:

$$\begin{aligned} R\&D_{it} = \beta_i &+ \beta_{1it}\, avencorp_{1it} + \beta_{2it}\, avendist_{2it} \\ &+ \beta_{3it}\, aventrade_{3it} + \beta_{4it}\, avenfdi_{4it} \\ &+ \beta_{5it}\, lock_{5it} + \beta_{6it}\, nat_{6it} + \beta_{7it}\, lgdp_{7it} \\ &+ \beta_{8it}\, yr_{8it} + \beta_{9it} non_{9it} + \mu_{it} \end{aligned} \qquad (4\text{-}2)$$

[38] The variables are elaborated in section 5 of this paper.

where *R&D* signifies research & development, *avencorp* denotes average corruption of the neighbouring countries, *avendist* indicates the average distance between the home country capital city and the neighbouring capital cities, *aventrade* shows the average trade of the neighbouring countries, *avenfdi* signifies the average foreign direct investment od the neighbouring countries, *lock* indicates to the landlocked dummy variable, *nat* signifies to the natural resources, *lgdp* denotes the GDP (log form), *yr* indicates to the year dummy variables and *non* denotes to the number of neighbours dummy variable.

$$\begin{aligned} corp_{it} = \beta_i + \beta_{1it}\, avenrnd_{1it} + \beta_{2it}\, avendist_{2it} \\ + \beta_{3it}\, aventrade_{3it} + \beta_{4it}\, avenfdi_{4it} \\ + \beta_{5it}\, lock_{5it} + \beta_{6it}\, nat_{6it} + \beta_{7it}\, lgdp_{7it} \\ + \beta_{8it}\, yr_{8it} + \beta_{9it} non_{9it} + \mu_{it} \end{aligned} \qquad (4\text{-}3)$$

where *corp* signifies corruption, *avenrnd* denotes average research & development of the neighbouring countries, *avendist* indicates the average distance between the home country capital city and the neighbouring capital cities, *aventrade* shows the average trade of the neighbouring countries, *avenfdi* signifies the average foreign direct investment od the neighbouring countries, *lock* indicates to the landlocked dummy variable, *nat* signifies to the natural resources, *lgdp* denotes the GDP (log form), *yr* indicates to the year dummy variables and *non* denotes to the number of neighbours dummy variable.

4.4.1 Two Stages Least Squares (2SLS)

Two-Stage least squares (2SLS) regression analysis is a statistical technique that is used in the analysis of structural equations. It is used when the dependent variable's error terms are correlated with the independent variables and that is the case in our (4-2) Model where the error terms of home innovation is correlated with the ***avencorp***. This problem called endogeneity problem which occurs when the error term is affecting the independent variables —avencorp— and therefore indirectly affecting the dependent variable —home innovation—. The rest of the variables in (4-2) model are considered exogenous variables where they have no direct or formulaic relationship, yet the endogenous variable is a problematic causal variable. Therefore, this problem must be solved in order to have accurate and robust results, consequently to solve the problem of endogeneity, instrumental variables are being used; which is used to create a new variable by replacing the problematic variable. The instrumental variables job is to correct for the endogeneity problem in the model, so IV should be are associated with the regressor only (not with error term and affecting the dependent variables) it just corrects for the error term to solve the endogeneity problem. The requirement for IV to correct for the endogeneity problem; the IV should be correlated with regressor. And it should not be correlated with the error term and it should not directly cause of the dependent variable.

After applying the IVs in the 2SLS model for Model (4-2), Durbin Wu-Hausman (DWH) test shall take place to check the exogenity and endogeneity of the suspect variable (avencorp). Furthermore, the main objective of the DWH is to compare coefficients of Ordinary Least Squares (OLS) and that of Two Stages Least squares (2SLS) (i.e. the null hypothesis states that the preferred estimator is the OLS) (Hausman, 1978). However, the test results support the application of the 2SLS technique for (4-2) model where home innovation is the dependent variable as we rejected the null hypothesis and concluded that 2SLS is the appropriate method, because there is a violation where OLS appeared to be biased —there is correlation between avencorp and the error term—. Therefore, to correct for this bias, we replaced the problematic/endogenous variable —avencorp—with the predicted *avencorp* values by using an instrumental variables.

In other words, 2SLS is about sequentially running two OLS regressions. The first OLS (first step) is regressing the problematic/endogenous which is avencorp variable on all the exogenous variables in the model including the instrumental variable which tends to correct for the problem of endogeneity. Then we obtain the predicted values of avencorp —endogenous variable— to find the fitted values, as the instrumental variable that is uncorrelated with the residuals. The second step is about regressing the initial equation by using the fitted values from the first step as instruments to replace the original endogenous variables. This model has been developed independently by Theil (1953) and Bassman (1957) as cited in Gujarati

(2009). The elaboration of the endogeneity problem and how to solve it is explained below. Firstly, we assume that the model (4-4) can be expressed as follows:

$$y = \alpha_1 x + \alpha_2 \varsigma + \mu \qquad (4\text{-}4)$$

Where y is the home innovation and $\boldsymbol{\varsigma}$ is the avencorp, independent variable, yet problematic, and x is the independent variable in the model and $\boldsymbol{\mu}$ is the error term. So, in order to solve the endogeneity problem, there is a need to use the 2SLS model, which is all about replacing the problematic/endogenous variable *avencorp* — with the predicted values of this variable. These predicted values can be calculated by adding the average of neighbouring governmental stability variable (*avenlaw, avenburc, avendemo*[39]), which is an instrumental variable. The predicted values of avencorp can be calculated from Model (4-5):

$$\varsigma = x\gamma_1 + \varrho\gamma_2 + e \qquad (4\text{-}5)$$

Where $\boldsymbol{\varsigma}$ is the predicted value of avencorp, x is the exogenous variable — the rest of the independent variables — and $\boldsymbol{\varrho}$ is the instrument variable which is represented by avenlaw, avenburc and avendemo. After calculating the predicted values for avencorp ($\boldsymbol{\varsigma}$), we substitute these values in the original model so that the new model can be written as:

$$y = \alpha_1 x + \alpha_2 \varsigma + \mu \qquad (4\text{-}6)$$

Where y is dependent variable — home innovation —, $\boldsymbol{\varsigma}$ is the predicted values for avencorp measured from (4-5), and x is the exogenous variables.

1. *Instrumental Variables (IV)*

The incentive for using instrumental variables is the existence of the endogeneity problem in the model, which means that OLS estimations are suspected to be biased

[39] *The IVs* are elaborated in section 5.

and inconsistent due to the correlation between the error terms of the dependent variable and at least one of the independent variables. However, the challenge that arises here is to find a valid IV which satisfies some requirements that are necessary to correct the problem of endogeneity. These requirements are:

1. The instrument must be correlated with the endogenous variable.
2. The instrument should not be correlated with the error term.

However, it is very difficult to find variables that meet these requirements because; theoretically, most variables which are correlated with the endogenous variable may have a direct impact on the dependent variable. Despite that, some instruments can be found, even though they may be considered weak, to identify the problematic variable weakly, and this is considered a significant problem. However, weak identification of the endogenous variables can cause another problem, that of inconsistency in the coefficients of 2SLS. Therefore, a chosen instrument shall be tested firstly to see whether it is either a weak instrument or it can solve the problem of endogeneity in the model.

4.4.2 Random Effects Model

According to the Hausman test results as shown in the Table (4-5) in section 5 of this chapter, P115, the random effects model represents a satisfactory model for the (4-3) Model where we are quantifying the impact of neighbour innovation on the home corruption. This random effects model can be expressed as (4-7):

$$Y_{it} = \alpha + \gamma_1 x_{1it} + \gamma_2 x_{2it} + \cdots + \gamma_k x_{kit} + (\varepsilon_i + \mu_{it}) \qquad (4\text{-}7)$$

Where Y signifies the home corruption and $\boldsymbol{x}$ indicates the independent variables which are given in model (4-3); $\boldsymbol{\mu}$ is the error term, $\boldsymbol{\varepsilon}$ is the standard random variable which differs for each country. $\boldsymbol{i}$ is an index of the country (140 countries) number while t indicates to the time (period of the study) 2003-2017 and α is a constant.

It is worth mentioning and according to Asteriou and Hall (2006) who stated that when the panel data is balanced (i.e. contains all existing countries' data), one might expect that the fixed effects model will provide better results compared with the random effects model. However, this is not applicable in our case, as we are using unbalanced panel data, where the sample contains limited observations of the existing countries — there is some missing data for certain countries in certain years —, and thus applying the random effects model might be more appropriate than the fixed effects model. Furthermore, using the random effects approach can handle the constant for each country as random parameters. This is not the only advantage of using random effects, but also using this approach allows for including additional variables that have equal values for all observations within a given country (Asterious & Hall, 2006, p.348). This means that it allows us to easily comprise dummy variables in the model, as in our case, we have year dummies, several neighbours dummies and la and lock dummy (i.e. almost 30 dummy variables).

4.5 Variables Description and Data source

This section presents the variables used in this paper, and it consists of three sub-sections. The first sub-section discusses in detail the dependent and independent variables as well as the logic theme behind including them in the models. Following this is a brief description of the sample data used in this study and the sources of the data. The third sub-section discusses the stationarity level of all variables using the unit root test.

4.5.1 The Variables

4.5.1.1 The Dependent Variable

1. ***Home Innovation***

Home country innovation is the dependent variable in the model (4-2), where it is expressed in research & development expenditure (R&D). It has been a candidate as an innovation proxy in many studies (Furman et al., 2002; Bottazzi and Peri, 2003; Hu and Mathews, 2005; Varsakelis, 2006; Smith et al., 2014; Lau et al., 2015). Also, R&D is one of the main tools used to gain a competitive advantage in science and technology for both the government and the private sector. This aspect reflects the extent to which a country allocates resources for growing the overall stock of knowledge, including fundamental research, applied for research and experimental development work that leads to new devices, products or processes.

Moreover, R&D is considered to be one of the most critical elements in improving the innovation capacity of nations (Audretsch and Feldman, 2004). Therefore, R&D is selected in this study as the primary output measure proxy of innovation, which is measured as a proportion of the gross domestic product (GDP) of each country.

2. Home Corruption

Home country corruption is the dependent variable in the model (4-3), expressed in this study by the Corruption Perception Index (CPI). This index claims to capture the informed views of analyses by business people and experts around the world, of corruption in different countries. Moreover, the organization of Transparency International (TI) is responsible for collecting the data of the country's corruption, and it is the global civil society organisation that is leading the fight against corruption. However, TI points out that corruption is challenging to be captured because it is happening 'behind closed doors and underneath the tables (Smith et al., 2014). D' and Ulman (2014) and many other researchers have used CPI to examine the effect of corruption. On the other hand, Anokhin and Schulze (2009); Lau et al. (2015); Mahagaonkar (2008) claim that CPI measures lack objectivity because it measures individuals' perceptions about the level of corruption in a particular country; yet it is generally accepted as the best corruption measure tool that the international community has come up with until now.

TI measures corruption as a scaled index starting from 0 to 100. The zero value is indicated to the most corrupted countries, while the one hundred value is assigned to the most uncorrupted countries or clean countries. For research and interpretation purposes, we reversed the scale of corruption in order to avoid any confusion. Therefore, the scale used in this study starts from 100 that has been assigned to very corrupted countries and ends at 0, which refers to most uncorrupted countries or clean countries.

4.5.1.2 The independent variables

In addition to our principal factors — neighbouring corruption & neighbouring innovation — we control for other variables which we expect to be significant to home innovation and home corruption, and they are categorized under three types: 1) geographical proximity; 2) economic openness, and 3) other variables. The choice of explanatory variables is inspired by the related empirical and theoretical literature.

1. Average corruption of the neighbouring countries (avencorp)

Avencorp is the main explanatory variable for Model (4-2) where the home country innovation is the dependent variable. In chapter 3 of this thesis, entitled "Is Corruption Detrimental to Innovation?" has concluded that home corruption is detrimental to home innovation and argues that corruption of the neighbours' countries can harm home country innovation, taking into account the fact that corruption is contagious, and this is empirically approved by many studies (Goel and Nelson, 2007; Attila, 2008; Becker et al., 2009; Lopez-Valcarcel et al., 2017; Feng et al., 2018). Furthermore, Figure (2-4)—in chapter 2 of this thesis— shows the world's corruption in 2018, which indicates that corrupted countries are clustered together and clean countries are also gathered together. Thus, we claim that corruption infection can affect home country innovation through affecting home country corruption, or in other words; we are argue that the contagious of corruption among countries can harm the innovation of home country.

In order to measure the neighbouring countries corruption ($\boldsymbol{avencorp_{hc}}$), we adopt Anselin and Moreno (2003); Becker et al. (2009) and Márquez et al. (2011) definition of a neighbour —two countries are sharing a common land border, hence islands are not considered as they do not have neighbours—. Thus, we measure the average corruption of neighbouring countries with the home country by summing up the corruption values of all neighbours, which share only a common adjacent border with the home country, meaning that neighbours with a maritime border are ignored. Then the summation of the corruption values is divided by the number of these neighbours. Thus, the neighbouring countries corruption ($\boldsymbol{avencorp_{hc}}$) is expressed as follows:

$$avencorp_{hc} = \frac{corp_{n1} + corp_{n2} + \cdots + corp_{nn}}{Number\ of\ neighbors} \qquad (4\text{-}8)$$

2. Average innovation of the neighbouring countries (aveninnov)

Aveninnov is our second main variable in this paper, where the home country corruption represents the dependent variable in (4-3) Model. Here we are argue that innovation of the neighbouring countries can spillover to home country via trade, FDI outflow and many other channels. This spillover of innovation to the home country can help in reducing the home corruption level because countries which trade more tend to be less corrupted. Hence, those countries are more exposed to international trade, which thus maintains a little room for effective policy tool to fight corruption by the policymakers. As per the results of the first paper, that corruption negatively impacts the level of innovation of the home country (meaning that countries with a high level of innovation have a lower corruption level compared to those having a low level of innovation, because those countries — which have a lower innovation level— invest less in the innovation sector). Mahagaonkar (2008) and Goedhuys et al. (2016) and others have argued that innovation could help countries to minimise the cost of corruption via focusing on innovation. Figure (2-2)—in chapter 2 of this thesis—, which shows World's R&D expenditures in 2015, demonstrates that countries which have a similar spending on innovation are neighbours. Hence, we are investigating whether focusing on the innovation of a country — neighbouring countries — via investing in the R&D sector does impact the corruption level of the home country.

In this paper, R&D expenditure is the proxy that used to represent innovation because it is the most appropriate and most common measure in quantifying the level of innovation capability (Acs et al., 2002; Furman et al., 2002; Cheung and Ping, 2004; Hu and Mathews, 2005; Varsakelis, 2006; Anokhin and Schulze, 2009; Fan, 2014; Smith et al., 2014; Lau et al., 2015). We can compute the average innovation of the neighbouring countries similarly to our previous computing of the neighbouring countries corruption. Thus, the average innovation of the neighbouring countries ($\boldsymbol{aveninnov_{hc}}$) is given by :

$$aveninnov_{hc} = \frac{innov_{n1} + innov_{n2} + \cdots + innov_{nn}}{Number\ of\ neighbors} \qquad (4\text{-}9)$$

3. Geographic closeness (avedist)

This variable is represented by the average circle distance between the capital city of the home country and its neighbours' capital cities. This distance can be easily calculated by using the Haversine formula (Sinnott, 1984), which computes the circle distance between two cities giving the latitude and longitudes of both cities (Chopde and Nichat, 2013). However, this distance represents the shortest distance over the earth's surface because it ignores any hills or valleys. Furthermore, the geographic distance (Geographic closeness or not) was also employed by several studies (Becker et al., 2009; Goel and Saunoris, 2014; Feng et al., 2018), but unlike this paper, they used distance weighted matrix technique to compute the geographical distance. However, even though the distance weighted matrix provides more accurate results compared to the average circle distance technique, it is more complicated, and not only does it requires more computational time but it is also only applicable for a balanced panel data type which is not available in this study.

The coordinates used to calculate the circle distance in (km) have been extracted from the Mayer and Zignago (2011) database. This variable — avedist — is calculated by summing up the distance between the home country's capital city and the neighbouring countries' capital cities. This mathematically can be expressed as:

$$avedist = \frac{dist_{ch\,\&\,cn1} + dist_{ch\&cn2} + \cdots + dist_{ch\&cnn}}{number\ of\ neighboures} \quad (4\text{-}10)$$

Innovation can be facilitated due to the proximity between the countries through interaction between agents and people. Hence, we argue that this closeness can optimise the innovation level between countries via flattening interactive learning (Boschma, 2005). Furthermore, the closeness between countries makes it easy for people to move (migrate) to the neighbouring country, and thus transfer norms from their home country to the host country.

Corruption can be contagious because of the closeness of cities to each other (Goel and Nelson, 2007; Zhu, 2009). Therefore, we argue that proximity of countries' capital cities has a positive consequence on corruption level; that corruption can travel from a country to another through flows of FDI and trade (B. Larraín and Tavares, 2004).

4. Landlocked

There are 49 landlocked countries around the world, of which we have included 38 because the rest do not have sufficient data for the variables which we are using to run the regressions. However, this variable is considered as a dummy variable which indicates a unity for a landlocked country and zero otherwise.

Innovation and being a landlocked country is a complicated situation because those countries are vulnerable to the neighbours, as everything they import/export must pass via their neighbour countries if they use land ways. We argue that being a landlocked country will not help to innovate, unless a sea is created (Casal and Selamé, 2015).

Corruption and landlocked countries have an interesting relationship. Countries with no marine borders that are surrounded by other countries are more likely to adopt he corrupt practices from the neighbouring countries — one country would induce individuals in the Border States to "learn" to be more corrupt. Moreover, landlocked countries are more accessible for people to move in or out compared to unlocked ones. Thus, the chance of carrying norms to neighbouring countries is increased. (Goel and Nelson, 2007; Zhu, 2009). Furthermore, being a landlocked country means being subject to bureaucratic procedures and paperwork, which means making everything slower and more expensive (Faye et al., 2004). All these issues might incentivise people to pay/accept bribes (i.e. corrupted) in order to make their lives easier.

5. Number of neighbours'

This variable is expressed as the countries which have common land borders with the home country —adjacent countries and it ignores maritime borders, which is island countries. We argue that a country can be affected by its neighbour as corruption is contagious and innovation can spillover. We claim that this influence increases as the number of neighbours increases. When a country is bordered by another country/countries, people who live on the borders can easily travel from their home country to the neighbouring country irrespective of their reasons for travelling or their ways of travelling (legally or illegally), and these people can transit their norms/ habits to the host country.

Furthermore, people who live on the borderlines between the neighbouring countries can take both countries habits, language, accent, etc. Therefore, we adopt the idea that more neighbours to a country might have a negative impact on the home country, because we assume that if the home country is surrounded by innovative countries, the innovation level in the home country can flourish, and consequently, corruption levels will be reduced. This fact is also applicable to corruption (i.e. we assume that if the home country is surrounded by corrupted countries, so the home country is more likely to be corrupt as well, and thus innovation levels might decrease because of the increase in levels of corruption). However, this variable is expressed as a dummy as follows:

Countries with one neighbor =1, otherwise 0. Countries with 2 neighbors =1, otherwise 0, and so on.

6. Average Trade of the neighbouring countries average)

The data of trade is expressed as a percentage of total GDP. Although corruption or innovation can be either greased or sanded by trade, however, in order to quantify this variable, we adopted the same definition of neighbour to *avencorp*, *aveninnov* and *avedist* —considering the countries which are sharing a common land border while ignoring the island counties—. Thus, the trade of the neighbouring countries' $\boldsymbol{aventrade}$ can be expressed mathematically as a proportion of GDP as follows:

$$aventrade = \frac{trade_{n1} + trade_{n2} + \cdots + trade_{nn}}{Number\ of\ neighbors} \qquad (4\text{-}11)$$

Innovation is considered as a contrary to trade association. Therefore, we argue that trade can enhance the innovation level in a country, and that trade openness can enhance the innovation level in a country by creating positive externalities which improve knowledge diffusion/flow. Furthermore, it increases competition between agents, through which the incentive increases, and at the final point it results in innovation (Grossman and Helpman, 1991; Roper et al., 2013; Papageorgiadis and Sharma, 2016; Akcigit et al., 2018).

Corruption: We argue that there is a negative association between trade and corruption. Hence, countries which trade more tend to be less corrupted, because those countries are more exposed to international trade, which leaves little room for effective policy tools for policymakers to fight corruption. Additionally, when a country is more open to trade, it means that this country has economic freedom as one of the determinants reducing corruption (Saha et al., 2009). Conversely, countries that are less exposed to international trade have higher levels of corruption, pointing to the fact that competition is lower in these countries, which results in larger rents. In other words, we argue that neighbouring trade can acts as a constraint on home corruption through spilling-over or positive externalities. Although many studies have investigated the relationship between corruption and trade at the home country (Ades and Di Tella, 1999; F. Larraín and Tavares, 2000; Bonaglia et al., 2001; Sandholtz and Gray, 2003; Saha et al., 2009), no one has addressed the impact of neighbouring trade openness on home corruption.

7. *Average foreign direct investment of the neighbouring countries-outflow,(avenfdiout)*

Although avenfdiout lies under the category of economic openness, the same definition of neighbour is adopted here as in the case of avencorp, aveninnov, avedist and average. The formula of avenfdiout is expressed as follows, where FDI-out is expressed as a proportion of GDP:

$$avenfdiout = \frac{fdiout_{n1} + fdiout_{n2} + \cdots + fdiout_{nn}}{number\ of\ neighbors} \qquad (4\text{-}12)$$

Innovation and FDI relationship became an increasingly important element in global economic development and an important catalyst for economic growth because FDI is an important vehicle of technology transfer between countries (Yang and Zou, 2008). However, Cheung and Ping (2004) examined the impact of FDI on the innovation level of the home country China, yet, in this paper, we are investigating if the neighbouring FDI can boost the innovation level in the home country.

Corruption and FDI have an interesting association, as we argue that FDI of the neighbouring countries can discourage corruption levels at the home country. Nevertheless, the economic literature on corruption demonstrated that countries which are highly corrupt, have a lower level of FDI (Mauro, 1995a; Wei, 2000). B. Larraín and Tavares (2004) studied the impact of corruption levels on the FDI at the country level, and F. Larraín and Tavares (2000) studied the opposite causality, while in our research we seek to examine and quantify if there is a relationship between the neighbouring countries FDI on the corruption level of the home country.

8. Natural resources rent

This variable is used in this paper to address its relationship with the country's corruption and innovation levels. We would like to examine the question of whether the abundance of natural resources is a blessing or a curse for the nations [40](Namazi and Mohammadi, 2018).

Innovation and abundance of natural resources is also complicated relationship. Therefore, we would like to understand if the richness of natural resources can help the countries to innovate. We claim that countries with natural resources are more likely to innovate for two reasons. Firstly, countries that heavily depend on natural resources tend to invest a fine proportion of their GDP in innovation. This is due to the fact that those countries understand both the finality of natural resources and the fact that these natural resources might lose their use in the future because of

[40] Because in the first paper which is titled "Is corruption detrimental to innovation?" results, this variable is insignificant with the innovation level.

technological inventions. Secondly, as Sachs and Warner (2001) argued, the abundance of natural resources could crowd-out the activities of the entrepreneurial, which could lead to more innovation.

Corruption and the abundance of natural resources are unlikely to have a good relationship. Countries that depend mainly on natural resources in their economic growth are easier to corrupt (Ades and Di Tella, 1999; Gatti, 1999; Leite and Weidmann, 1999; Treisman, 2003; Lambsdorff, 2007; Goel and Nelson, 2010). Therefore, we are controlling for the natural resources and argue that the country's natural resource endowments create unique opportunities for rent-generation and rent-seeking.

9. Gross domestic product (GDP)

GDP is used as an economy scale for the countries. Researchers have long debated the relationship between corruption and GDP: for instance, Ahmad et al. (2012) and Lau et al. (2015) have concluded that corruption can hinder economic growth. Conversely, some have found that corruption can grease the economic growth of countries (Mauro, 1995b; Aidt, 2003). However, in our study, we argue that corruption is slowing down or sanding the wheel of economic growth of the nations (Méon and Sekkat, 2005; Swaleheen, 2011). Contrarily, innovation and GDP have a positive relationship (Rosenberg, 2004; Galindo and Méndez-Picazo, 2013), where countries that are growing in a very fast manner such as China and Singapore are investing a very fine proportion of their GDP in the innovation sector. Innovation is the new trend for the countries to develop because it is the main pillar in the economic growth equation (Schumpeter, 1912; Solow, 1956; Mansfield, 1972; King and Levine, 1993; Aghion et al., 2005; Adak, 2015).

10. Year Dummy (2003-2017)

Dummy variable equals 1 for a given year and 0 for all other years, where 2003 is considered as the base year. Therefore, we omitted this year in the regressions process to avoid the dummy variable trap problem. Because in this paper, we use panel regressions technique, to avoid any aggregate trends which have nothing to do with the casual relationships, we have to control for the year effects on any relationship. Since both our Model (4-2) and (4-3) favour random effects estimators and in order to make sure that the years' effects on variables for a given year have the same amount, the years can be included in the fixed part as discrete time dummies. Thus, to control for time-specific effects expected to affect the whole sample over time, these effects are included as controls in the random effects model.

11. Instrument Variable (IV)

Because of the endogeneity problem in Model (4-2) where avencorp is correlated with the home innovation's error term, therefore three IVs have been used to correct for the problematic variable which are average law and order of neighbouring countries (avenlaw), average bureaurcy quality of neighbouring countries (avenburcq) and average democratic accountability of neighbouring countries (avendemo)[41]. The responsible organization for collecting this data is the Political Risk Services group. We chose those variables because the underlying hypothesis is that innovation which involves a commitment to the future is more likely in a stable political environment[42].

Nevertheless, the same definition of neighbour is adopted here, similarly to avencorp, aveninnov, avedist, aventrade and avenfdiout variables. The mathematical formula of $\boldsymbol{avenlaw, avenburc\ and\ avendemo}$ are expressed as follows:

$$avenlaw = \frac{law_{n1} + law_{n2} + \cdots + law_{nn}}{number\ of\ neighbors} \qquad (4\text{-}13)$$

[41] For more details on the definition and methodology of measuring those variables please see (https://www.prsgroup.com/wp-content/uploads/2012/11/icrgmethodology.pdf).

[42] Other variables like average Government stability of neighbouring countries (avengovsab), average ethnic tension of neighbouring countries have been used to correct for the problematic variable (avencorp), but the results were not significant and couldn't solve the endogeneity problem.

4.5.2 The sample

The data which we are using to run the regression is an unbalanced panel dataset. Nevertheless, the data is unbalanced because the sources which we extracted the data from do not have the full dataset. The World Bank is the main source for the data in this paper. The World Bank has reported several reasons why data is unavailable for some indicators, some countries and some years. Firstly, some indicators are derived from sporadic surveys and are only available for some years. Secondly, some data sets or indicators are only available from the year they were initiated. Thirdly, some countries do not regularly report data due to conflict, lack of statistical capacity, or other reasons. Fourthly, some countries do not have data for earlier years simply because they did not exist. Therefore, we have some missing observations for some periods in some countries. Hence, we are using the annual data of 140 countries over the period 2003-2017.

However, Table (4-1) shows a summary of the variables and the data source used in this paper. Table (4-2) describes the summary statistics of the dependent variables and the explanatory variables, which include their number of observations, mean, standard deviation, minimal value and maximum value. Table (4-3) shows the countries which are included in the regression, and they are divided region-wise according to the World Bank division.

Table 4-1. The Glossary of Variables

Symbols of the variables		Name of the Variable	Variable definition	Source of data	Unit of Measurement
Dependent variables	Rnd	Innovation	Research & Development expenditures (% of GDP)	World bank	% of GDP
	Corp	Corruption	Corruption Perception Index (0 indicates to clean countries, 100 indicates to corrupted countries)	Transparency International organisation	Index
Independent variables	Aveninnov	Average Innovation of the neighbouring countries	Average of Research & Development expenditures of the neighbouring countries (% of GDP)		% of GDP
	Avencorp	Average corruption level on the neighbouring countries	Average Corruption Perception Index -0 indicates to clean countries, 100 indicates to corrupted countries- of the neighbouring countries		Index
	Nat	Natural Resources	Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents (% of GDP)	World bank	% of GDP
	GDP	Log GDP	the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products	World bank	Log form
	avedist2	Geographical Closeness	The average distance between the home country's capital city and its neighbours' capital cities. The distance is in kilometres (km)	(Zignago, 2011)	km
	Average	Average trade of the neighbouring countries	Average of trade of the neighbouring countries (% of GDP)	World bank	% of GDP
	Avenfdiout	Average FDI outflow of the neighbouring countries	Average of outward of Foreign direct investment of the neighbouring countries (% of GDP)	World bank	% of GDP
	Lock	Landlocked dummy	One if the country is landlocked, 0 otherwise		1,0
	d20**	Year Dummy			
	no*	Number of Neighbours Dummy	Countries which have land borders with the home country Countries with no neighbours =1, otherwise 0. Countries with one neighbour =1, otherwise 0. And so on.		1,0

Table 4-2. Summary of the statistics results

Variable		Observations	Mean	Standard Deviation	Min	Max
Innovation (R&D) (% of GDP)		2,331	0.435	0.797	0	4.405
Corruption		2,221	57.620	21.347	3	100
Average Innovation of the neighboring countries (% of GDP)		1,950	0.549	0.695	0	3.087
Average corruption level on the neighboring countries		1,948	60.860	15.283	6.333	84.667
Natural Resources (% of GDP)		2,331	8.021	12.180	0	64.111
Log GDP		2,273	4.475	1.983	0.013	9.963
Geographical Closeness (km)		1,950	0.965	0.612	0.161	3.055
Average trade of the neighboring countries (% of GDP)		1,950	77.041	30.563	0	291.020
Average FDI outflow of the neighboring countries (% of GDP)		1,950	1.954	4.057	0.000079	58.008
Land lock dummy		2,360	0.220	0.414	0	1
Year Dummy	2003	2,360	0.064	0.244	0	1
	2004	2,360	0.065	0.247	0	1
	2005	2,360	0.068	0.251	0	1
	2006	2,360	0.069	0.253	0	1
	2007	2,360	0.066	0.249	0	1
	2008	2,360	0.064	0.245	0	1
	2009	2,360	0.063	0.243	0	1
	2010	2,360	0.064	0.244	0	1
	2011	2,360	0.069	0.253	0	1
	2012	2,360	0.069	0.253	0	1
	2013	2,360	0.067	0.250	0	1
	2014	2,360	0.068	0.252	0	1
	2015	2,360	0.068	0.252	0	1
	2016	2,360	0.070	0.256	0	1
	2017	2,360	0.067	0.250	0	1
Number of Neighbors Dummy	countries with 1 neighbors	2,360	0.174	0.379	0	1
	countries with 2 neighbors	2,360	0.059	0.236	0	1
	countries with 3 neighbors	2,360	0.153	0.360	0	1
	countries with 4 neighbors	2,360	0.140	0.347	0	1
	countries with 5 neighbors	2,360	0.156	0.363	0	1
	countries with 6 neighbors	2,360	0.127	0.333	0	1
	countries with 7 neighbors	2,360	0.073	0.260	0	1
	countries with 8 neighbors	2,360	0.058	0.235	0	1
	countries with 9 neighbors	2,360	0.017	0.131	0	1
	countries with 10 neighbors	2,360	0.023	0.151	0	1
	countries with 11 neighbors	2,360	0.006	0.077	0	1
	countries with 12 neighbors	2,360	0.006	0.079	0	1
	countries with 13 neighbors	2,360	0.006	0.079	0	1

Notes:
1) The summary of statistics is provided based on a period from 2003 to 2017 for 140 countries worldwide.
2) The dataset used in this paper is unbalanced, where there are some gaps in the year for some countries due to the unavailability of the data.

Table 4-3. List of countries included in this study

Europe & Central Asia	Sub-Saharan Africa	Latin America & Caribbean	Middle East & North Africa	East Asia & Pacific	South Asia	North America
Albania	Angola	Argentina	Algeria	Cambodia	Afghanistan	Canada
Armenia	Benin	Bolivia	Bahrain	China	Bangladesh	United States
Austria	Botswana	Brazil	Egypt, Arab Rep.	Hong Kong SAR, China	Bhutan	
Azerbaijan	Burkina Faso	Chile	Iran, Islamic Rep.	Lao PDR	India	
Belarus	Burundi	Colombia	Iraq	Malaysia	Nepal	
Belgium	Cameroon	Costa Rica	Israel	Mongolia	Pakistan	
Bosnia and Herzegovina	Central African Republic	Ecuador	Jordan	Myanmar	Sri Lanka	
Bulgaria	Chad	El Salvador	Kuwait	Singapore		
Croatia	Congo, Dem. Rep.	Guatemala	Lebanon	Thailand		
Czech Republic	Congo, Rep.	Guyana	Libya	Vietnam		
Denmark	Cote d'Ivoire	Honduras	Morocco			
Estonia	Equatorial Guinea	Mexico	Oman			
Finland	Ethiopia	Nicaragua	Qatar			
France	Gabon	Panama	Saudi Arabia			
Georgia	The Gambia	Paraguay	Tunisia			
Germany	Ghana	Peru	United Arab Emirates			
Greece	Guinea	Suriname	Yemen, Rep.			
Hungary	Guinea-Bissau	Uruguay				
Italy	Kenya	Venezuela, RB				
Kazakhstan	Lesotho					
Kosovo	Liberia					
Kyrgyz Republic	Malawi					
Latvia	Mali					
Lithuania	Mauritania					
Luxembourg	Mozambique					
Macedonia, FYR	Namibia					
Moldova	Niger					
Montenegro	Nigeria					
Netherlands	Rwanda					
Norway	Senegal					
Poland	Sierra Leone					
Portugal	South Africa					
Romania	South Sudan					
Russian Federation	Sudan					
Serbia	Tanzania					
Slovak Republic	Togo					
Slovenia	Uganda					
Spain	Zambia					
Sweden	Zimbabwe					
Switzerland						
Tajikistan						
Turkey						
Turkmenistan						
Ukraine						
United Kingdom						
Uzbekistan						

4.5.3 Unit root test

We are using an unbalanced panel dataset of 140 countries over the period 2003-2017. The appropriate unit root test to be used is the Fisher-type test because it does not require strongly balanced data, and the individual's series can have gaps (Baltagi, 2008; p.244-245). Therefore, we are using a Fisher-type test (Fisher, 1932) using ADF and PP tests (Maddala and Wu, 1999; Choi, 2001). Furthermore, the lag lengths of the individual augmented Dicky-Fuller tests are allowed to differ. Fisher-type tests were used to test the null hypothesis, which represents the presence of "individual unit root". The Fisher-type test uses p-value from unit root tests for each cross-section (i.e. country i). This test is an asymptotically chi-square distributed with 2N degrees of freedom ($\boldsymbol{T_i} \rightarrow \infty \; \boldsymbol{for\ finite\ N}$) (Nell and Zimmermann, 2011). The formula of the test looks as follows:

$$P = -2\sum_{i=1}^{N} ln\, p_i \tag{4-14}$$

Furthermore, the results show that all variables used in this paper are stationary. However, Table (4-4) shows the results of the unit root test for all variables. According to the results shown in this table, the null hypothesis is strongly rejected because the P value is less than 0.05. Thus, it is assumed that all the series are stationary at the same level (no unit root).

Table 4-4. Unit Root Results

The variables	Individual intercept/trend/none	ADF- Fisher Chi-Square			PP-Fisher Chi-Square		
		Observ ations	cross sections	T-Stat	observati ons	cross sections	T-Stat
Corruption	Individual effects, individual linear trends	2181	176	557.240***	2289	176	586.047***
Research & Development	Individual effects, individual linear trends	1676	123	341.749***	1722	123	432.139***
Average Corruption of Neighbouring Countries	Individual effects, individual linear trends	1965	146	448.291***	2042	146	467.550***
Average trade of Neighbouring Countries	Individual effects, individual linear trends	1966	146	364.304***	2044	146	412.074***
Average R&D Neighbouring Countries	Individual effects	1930	142	397.053***	1988	142	362.166***
Average Government stability of Neighbouring Countries	Individual effects, individual linear trends	1837	147	414.809***	1911	147	341.671**
Average FDI outflow of Neighbouring Countries	Individual effects, individual linear trends	1943	144	666.788***	2016	144	823.552***
Natural Resources Rent	none	2423	174	488.599***	2436	174	485.780***
log GDP	Individual effects, individual linear trends	2281	172	446.572***	2389	172	420.059***
legend: * p<0.1;** p<0.05; *** p<0.01							
Ho: All panels contain unit roots							
Ha: At least one panel is stationary							

4.6 Empirical Results and Discussion

This section is divided into two sub-sections, the first sub-section presents the interpretations of the results along with the discussion of Model (4-2) where home innovation is the dependent variable. While the second sub-section presents the results and the discussion of the model where home corruption is the dependent variable.

4.6.1 Home Innovation

Table (4-5) presents the results of Model (4-2) where we address the impact of the neighbouring corruption on the home innovations — which is the dependent variable. According to DWH test results, the 2SLS method is the appropriate one because of the endogenity problem where avenlaw, avenburc and avendemo are being used as an instrument variable to correct for the problem.

Table 4-5 Empirical Results of Regression Analysis – Home Innovation

The Variables	Home Innovation		
	Fixed Effects	**Random Effects**	**2SLS**
Average Corruption of Neighbouring Countries	-0.011 (-3.487)	-0.018 (-7.299)	-0.022*** (-4.008)
Average trade openness of the neighbouring countries	-0.001 (-1.825)	-0.002 (-2.206)	0.000 (-0.251)
Average FDI outflow of the neighbouring countries	-0.009 (-2.613)	-0.007 (-2.143)	-0.007** (-2.389)
Geographical closeness	(omitted)	-0.305 (-3.675)	-0.253*** (-2.528)
Land Lock	(omitted)	0.065 (0.592)	0.018 (0.145)
Natural Resources	-0.009 (-6.323)	-0.01 (-6.873)	-0.005*** (-3.629)
Log GDP	0.245 (3.443)	0.142 (4.99)	0.11*** (2.823)
2004	0.024 (0.536)	0.029 (0.652)	0.019 (0.486)
2005	0.004	0.014	0.001

The Variables	Home Innovation		
	Fixed Effects	Random Effects	2SLS
	(0.096)	(0.306)	(0.02)
2006	0.015 (0.326)	0.031 (0.691)	0.017 (0.425)
2007	0.023 (0.473)	0.042 (0.922)	0.025 (0.604)
2008	0.064 (1.269)	0.091 (1.978)	0.073* (1.689)
2009	-0.007 (-0.152)	0.018 (0.402)	0.028 (0.684)
2010	0.022 (0.425)	0.053 (1.147)	0.055 (1.298)
2011	0.033 (0.631)	0.071 (1.557)	0.06 (1.378)
2012	0.002 (0.037)	0.025 (0.54)	0.008 (0.198)
2013	-0.033 (-0.601)	-0.004 (-0.095)	-0.012 (-0.292)
2014	-0.061 (-1.095)	-0.034 (-0.749)	-0.039 (-0.946)
2015	-0.161 (-2.815)	-0.132 (-2.886)	-0.121*** (-2.89)
2016	-0.645 (-11.238)	-0.614 (-13.487)	-0.601*** (-14.504)
2017	-0.741 (-12.055)	-0.709 (-14.754)	(omitted)
2 Neighbour	(omitted)	-1.099 (-2.052)	-1.227*** (-2.055)
3 Neighbour	(omitted)	-1.072 (-2.048)	-1.217*** (-2.101)
4 Neighbour	(omitted)	-0.905 (-1.731)	-1.062* (-1.835)
5 Neighbour	(omitted)	-0.985 (-1.878)	-1.099** (-1.898)
6 Neighbour	(omitted)	-1.131 (-2.156)	-1.256** (-2.173)
7 Neighbour	(omitted)	-0.958 (-1.828)	-1.094** (-1.896)
8 Neighbour	(omitted)	-0.891 (-1.678)	-0.983 (-1.681)

The Variables	Home Innovation		
	Fixed Effects	Random Effects	2SLS
9 Neighbour	(omitted)	-1.155 (-2.014)	-1.264*** (-2.001)
10 Neighbour	(omitted)	-0.693 (-1.258)	-0.775 (-1.273)
11 Neighbour	(omitted)	-0.647 (-0.931)	-0.87 (-1.136)
12 Neighbour	(omitted)	-0.644 (-0.95)	-0.768 (-1.025)
Constant	0.318 (0.753)	2.456 (4.022)	2.814*** (3.51)
Number of Observations	1876	1876	1753
Number of Countries	140	140	140
t-statistics is reported in the parentheses ( ). Robust standard errors have been used.	legend: * p<0.1;** p<0.05; *** p<0.01		
Hausman test: Prob>chi	0.3943		
Hausman test: Prob>chi		0.000	

Average neighbouring corruption — *avencorp* —is our main variable. The results show that avencorp is significantly and negatively affecting the home innovation level; when the avencorp index rises by one point, the home innovation decreases by 0.02239 percentage points. This reduction in the home innovation is due to the contagious corruption from the neighbouring countries as a result of the neighbouring corruption affecting home corruption (Goel and Nelson, 2007; Attila, 2008; Becker et al., 2009; Lee and Guven, 2013; Feng et al., 2018; Sui et al., 2018) and this impact reaching home innovation. This negative impact in the home innovation can be sensed through the misallocations of resources, eroding trust, rising costs —as we elaborated in the first paper.

According to Table (4-5), it can be seen that geographical closeness is negatively affecting the home innovation. When the distance between home country's capital city and its neighbour's capital cities increases by 1 km, the home innovation decreases by 0.253 percentage points. Due to the geographical closeness, the home innovation is being harmed in an undesirable way. However, several researchers argued that innovation spill-over from neighbouring countries is geographically constrained and it can be captured within the home country innovation (Griliches, 1991; Audretsch and Feldman, 1996). Furthermore, our results reveal that being landlocked or not has no impact on home innovation, yet, (Boschma, 2005) claims that geographical proximity has a negative impact on the home innovation levels due to the problem of lock-in. Additionally, MacKellar et al. (2000) confirm that landlocked countries experience slower economic growth — taking into consideration that innovation is a main pillar in the economic growth model. Regarding the number of neighbours, where the results show a negative impact on home innovation, more neighbours means better innovation. Furthermore, the results show a fluctuating trend depending on the number of neighbours. As the number of neighbours' increases, the negative impact on the home innovation slightly decreases—. Thus, we can conclude that having more neighbours is better for home innovation. Yet, the conclusion remains the same: neighbouring countries impact home innovation negatively because, countries which have common borders with several countries are more likely to expect more migrants, people and their habits, imitation behaviour which consequently affect the economic growth. Hence, those countries will focus resources—on solving the problems brought by those people rather than focusing in improving the home innovation sector Eventually, having a limited number of neighbours does cost less than having many neighbours.

Referring to economic openness, our results reveal that openness of the neighbouring countries has an adverse impact on home innovation. The more the neighbouring countries invest outside their countries, the less likely home innovation is to flourish. In other words, for the neighbouring country which invests more outside their home country, the innovation of the neighbouring country can be evaded, as the resources are being devoted outside their countries. So, the home country cannot take advantage of the knowledge spill-over of the FDI. On the other hand, trade openness has no impact on the home country, not as we argued that the openness could positively affect innovation where openness can help the country to exchange technology/knowledge. Through openness, knowledge can spill over. Nevertheless, in the case of this paper, the results are different, where the trade of the neighbouring countries has no impact on the level of innovation in the home country. This is unlike Akcigit et al. (2018) who demonstrate that trade can help innovation to flourish.

Furthermore, we controlled for other variables which are directly related to the home country; an abundance of natural resources and GDP. The abundance of natural resources has a negative impact on home innovation. Countries which depend on natural resources are less likely to invest in the innovation sector because most of the countries which depend mainly on the natural resources in their GDP are from developing countries where innovation is yet to come because at the current time those countries are investing in the infrastructure sector. Our economy scale variable, which is represented in the log form of the GDP shows a positive significant impact on the home innovation. Countries with relatively high GDP tend to invest more in the innovation sector, a reliable portion of their GDP in the home innovation. When the GDP increases by 1%, the innovation in the home country increase by 0.1096 percentage points.

In summary, according to our results, we can conclude that contagious corruption— neighbouring corruption— can negatively and significantly affect home innovation through impacting home corruption, and it has been demonstrated by several researchers that corruption can travel from a country to another (Goel and Nelson, 2007; Attila, 2008; Becker et al., 2009; Feng et al., 2018; Sui et al., 2018). The closeness of the capital cities distresses home innovation rather heavily. Furthermore, being surrounded by corrupt countries in a situation where countries which are relatively close to each other tend to exhibit imitation behaviour, corruption is one of those behaviours (Accinelli and Carrera, 2012). Therefore, geographical closeness and having neighbours are impact home innovation negatively. Moreover, when neighbouring countries invest more in other countries, home innovation decreases; because the resources are being invested outside the home and also because of neighbouring corruption, the home country cannot take advantage of knowledge spill-over from the host countries, countries that welcome the FDI. Countries with abundant natural resources invest less in the innovation sector, as most of those countries are developing countries that mainly focus on infrastructure. Furthermore, countries with a higher GDP, tend to invest a fine proportion in the innovation sector.

4.6.2 Home Corruption

The results of Model (4-3) where home corruption is the dependent variable are shown in Table (4-6). This model is the main objective is to examine the impact of the neighbouring innovation on the corruption of the home country. Furthermore, according to Hausman test, a random effects model is the appropriate model to run the regression.

Table 4-6. Empirical Results of Regression Analysis- Home Corruption

The Variables	Home Corruption		
	Fixed Effects	**Random Effects**	**2SLS**
Average Innovation of the neighbouring countries	-0.499 (-1.428)	-0.874 (-1.823)	-53.444 (-2.08)
Average trade openness of the neighbouring countries	-0.059 (-6.427)	-0.055 (-3.062)	-0.1 (-1.632)
Average FDI outflow of the neighbouring countries	-0.014 (-0.368)	-0.027 (-0.478)	-0.248 (-1.705)
Geographical closeness	(omitted)	11.47 (4.543)	-4.821 (-0.579)
Land Lock	(omitted)	-9.283 (-2.647)	9.208 (0.971)
Natural Resources	-0.075 (-4.238)	-0.069 (-2.717)	-0.245 (-1.907)
Log GDP	-9.625 (-11.628)	-7.507 (-8.609)	3.625 (0.701)
2004	0.411 (0.759)	0.298 (0.804)	1.249 (1.266)
2005	0.569 (1.054)	0.346 (0.687)	0.492 (0.568)
2006	1.483 (2.694)	1.126 (1.829)	1.67 (1.445)
2007	2.149 (3.729)	1.681 (2.373)	2.75 (2.082)
2008	2.702 (4.561)	2.126 (2.798)	4.441 (2.514)
2009	2.007 (3.496)	1.497 (1.995)	2.957 (2.29)
2010	2.647 (4.43)	2.029 (2.706)	5.112 (2.459)

The Variables	Home Corruption		
	Fixed Effects	Random Effects	2SLS
2011	3.462 (5.664)	2.717 (3.58)	5.146 (2.388)
2012	1.141 (1.818)	0.324 (0.356)	2.961 (1.213)
2013	1.712 (2.656)	0.812 (0.877)	1.698 (0.945)
2014	1.112 (1.704)	0.163 (0.171)	-0.171 (-0.095)
2015	0.927 (1.388)	-0.098 (-0.103)	-4.207 (-1.538)
2016	1.023 (1.445)	-0.234 (-0.216)	-33.407 (-1.997)
2017	0.167 (0.219)	-1.161 (-0.979)	(omitted)
2 Neighbour	(omitted)	-32.994 (-4.57)	6.352 (0.256)
3 Neighbour	(omitted)	-15.946 (-2.432)	12.599 (0.717)
4 Neighbour	(omitted)	-19.777 (-2.686)	13.173 (0.7)
5 Neighbour	(omitted)	-14.536 (-1.978)	7.559 (0.525)
6 Neighbour	(omitted)	-4.533 (-0.739)	7.778 (0.725)
7 Neighbour	(omitted)	-1.738 (-0.3)	3.087 (0.335)
8 Neighbour	(omitted)	-4.745 (-0.689)	3.405 (0.327)
9 Neighbour	(omitted)	-1.731 (-0.283)	-13.509 (-1.38)
10 Neighbour	(omitted)	-8.311 (-1.479)	4.51 (0.374)
11 Neighbour	(omitted)	-9.51 (-1.926)	12.386 (0.969)
12 Neighbour	(omitted)	12.231 (5.609)	39.09 (2.849)
Constant	109.048 (27.956)	103.955 (12.055)	78.126 (4.192)
Number of Observations	1830	1830	1707
Number of Countries	140	140	140

The Variables	Home Corruption		
	Fixed Effects	Random Effects	2SLS
t-statistics is reported in the parentheses ( ). Robust standard errors have been used.		legend: * p<0.1;** p<0.05; *** p<0.01	
Hausman test: Prob>chi	0.9684		
Hausman test: Prob>chi		1.000	

The results of Model (4-3) where home corruption is the dependent variable are shown in Table (4-6). This model is the main objective to examine the impact of the neighbouring innovation on the corruption of the home country. According to Hausman test, a random effects model is the appropriate model to run the regression.

The results of the home corruption model reveal that neighbouring innovation has a negative impact on home corruption. When neighbouring innovation increases by one percentage point, home corruption decreases by 0.8736 index points. We can justify that if a country is surrounded with highly innovative countries, the home country's innovation can rise via knowledge spill-over from the neighbouring countries—and because the neighbouring countries show imitation behaviour, the home corruption can decrease (Johari and Ibrahim, 2017). Thus, focusing on improving innovation in one country can help other countries to focus on the innovation precisely because of knowledge spill-over, which indirectly can help corruption to decrease at the home country. Corruption in the home is adversely affected by the innovation of the neighbouring countries. Accordingly, the results reveal that focusing on neighbouring innovation can help to reduce the home corruption because vanishing corruption is not only one country's duty, yet it is everyone's duty (Attila, 2008).

Geographical closeness and home corruption have an interesting relationship and been argued by many researchers (Goel and Nelson, 2007; Becker et al., 2009; Feng et al., 2018; Sui et al., 2018), however, our results are more interesting. This is because the geographical closeness shows that the countries which are close to each other are more likely to be corrupted: when the distance between the home country's capital city and it is neighbouring' capital city increases by 1 km, the home corruption increases by more than 11 points in the corruption index. Because of contagious corruption occurring over geographic boundaries (Sui et al., 2018) and geographical closeness can help the corruption to travel as this closeness facilitates corruption links between cities (Correa et al., 2016). Moreover, geographic distance can affect the home corruption through openness, i.e. trade and FDI (Zhu, 2009). Contrarily to this, the landlocked result is quite different in that it reveals that the landlocked countries tended to be less corrupt. However, Faye et al. (2004) argue that landlocked countries are more corrupt than those with a sea access, and this is because landlocked countries live under the mercy of their neighbours. Landlocked countries are more likely to use the roads to cross international borders, and are thus subject to bureaucratic procedures which might lead to direct costs, even bribes—, and all this might slow down pace and increase costs (Faye et al., 2004). The number of neighbours' results show that being neighboured by fewer countries makes one less likely to be corrupt, because more neighbours mean more migration, norms, people, and imitation behaviour. Consequently they are more likely to be corrupted. The countries with 12 neighbours reveal that more neighbours mean and increase by 12 points in the corruption index scale

Economic openness and home corruption relationship have been debated among researchers (F. Larraín and Tavares, 2000; Bonaglia et al., 2001; Gokcekus and Knörich, 2006; O'Trakoun, 2017). Our results show that the neighbouring trade can play a constraint on home corruption. When neighbouring countries trade increases by one percentage, the home corruption is less likely to be corrupt by 0.0549 points in the corruption index. Thus, not only the home country trade can deter home corruption (F. Larraín and Tavares, 2000; Bonaglia et al., 2001; Gokcekus and Knörich, 2006; Saha et al., 2009; O'Trakoun, 2017), but also the openness of the neighbouring countries can help the home country to reduce its domestic corruption level. This is because their openness to the world and while dealing with other countries for business purposes, both countries (home and host) tend to be more careful about accepting any corruption activities such as like bribes, nepotisms to get advantage to enter the market because of their consequences.

We controlled for other variables which relate to the home country corruption, that is natural resources and GDP. The results indicate that the abundance of natural resources in nations is adversely affecting the home corruption: when the share of natural resources in the national income increases by one percentage, home country corruption drops by 0.69 points in the corruption scale. This might be because those countries are investing in anticorruption campaigns aiming to reduce corruption. However, our results clearly contradict some other researchers' results. For instance, Ades and Di Tella (1999) conclude that countries which depend heavily on natural resources are easy to corrupt. , At the same time, however, Sui et al. (2018) claim that the abundance of natural resources has no impact on corruption level. Furthermore, in the economy scale variable which is represented in the log form of the GDP, the result reveals that countries with higher GDP tend to be cleaner by 7 points of the corruption scale, so wealth can help countries be clean from corruption.

According to our results, focusing on innovation in one country, can help to reduce corruption in a neighbouring country through knowledge spill-over. Furthermore, geographic closeness has a positive relationship with home corruption, because this closeness can help the movement of people between countries carrying norms from a country to another. Beside this, openness to the world via trade can deter corruption: openness and dealing with other countries means committing to the international laws and rules which give the home country very little room to corrupt. Finally, countries which are characterised with similar economic development are more likely to spread corruption (Sui et al., 2018). Thus, countries with higher GDP tend to be less corrupt than those with smaller GDP.

In summary, when comparing the two models, we can see that results are consistent for the *avencorp* and *aveninnov* where home innovation and home corruption are the dependent variables, respectively. The results show that neighbouring corruption can harm home innovation and neighbouring innovation can help the home country to be less corrupt by negatively affecting corruption levels at home country. We can conclude that the neighbouring corruption and neighbouring innovation can travel to affect home innovation and home corruption, yet with varied impact —neighbouring corruption is impacting home innovation in more significant means that the neighbouring innovation impacting home corruption. Likewise, geographical closeness appears to be not a good factor for both models, neither for home innovation nor home corruption. Geographical closeness affects home corruption more than its affects the home innovation —the closer capital cities are, the more likely they are to exhibit imitation behaviour, especially the corruption activities. Furthermore, regarding economic openness, the results show that openness is affecting home innovation statistically, yet economically the impact factor is not reliable, openness in fact, is a constraint to corruption. Also, our economy scale variable —GDP— shows that the countries with more GDP are more likely to invest in the home innovation and less likely to be corrupted.

4.7 Conclusion

This study has empirically presented the influence on the home country innovation of contagious corruption as well as the impact of neighbouring innovation on the home country corruption, using a dataset of 140 countries over 15 years period. Our findings reveal that home innovation activities are being negatively affected by neighbouring corruption. This confirms that corruption is contagious, and consequently, it will impact the economic growth which is consistent with the literature (Goel and Nelson, 2007; Attila, 2008; Becker et al., 2009; Feng et al., 2018; Sui et al., 2018). Furthermore, our outcomes demonstrate that the innovation of neighbouring countries could help the home country to be less corrupt (i.e. cleaner).The results show also that geographical closeness significantly affects both home corruption and home innovation, however, it has more impact on home corruption than home innovation. This might be due to the closeness of capital cities in that they have more of a tendency to provoke imitation behaviour, especially for corruption activities. Moreover, the openness of neighbouring countries can play a constraint factor on home corruption in that openness helps countries to reduce the probability of corruption, therefore, neighbouring countries' activities have an impact on the home country irrespective of the type of impact and vice versa. In the end, we can conclude that neighbouring countries corruption can travel to reach the home country and consequently affecting the home innovation.

In line with the empirical evidence herein, we recommend some policy considerations. First our results suggests that combating corruption is thus not a responsibility of one individual, neither one country nor a single organization but, it is everyone's responsibility. Furthermore, geographical proximity plays a leading role to worsen things in the countries via travelling of corruption and harming innovation, therefore governmental policymakers should set rules and regulations at the borderlines —as it is easier for the corruption to travel—to fight corruption locally and thus reduce home corruption. These activities then can travel and spill-over into neighbouring countries and help those to be cleaner that is i.e. considered as positive externalities (Correa et al., 2016; Feng et al., 2018).

4.8 Limitations and Future Research Directions

This research project could be extended in some ways, for example, by gathering some additional information for more countries from different resources using different proxies to represent innovation and corruption. Furthermore, it is worth using a different approach to calculate the geographical closeness to get more robust results. We are planning to measure the same controlled variables yet using different tactics such as the ratio of the variables instead of the average of variables to the home country and its neighbours in order to get more accurate and valid results. Furthermore, this study can be extended to address the same issues regionaly, where countries share the same borders, habits, sometimes language and culture.

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This declaration concerns the article entitled:									
Can Corruption Distress Research Productivity?									
Publication status (tick one)									
Draft manuscript	X	**Submitted**		**In review**		**Accepted**		**Published**	

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Signed	**Maryam Al-Bulushi**	**Date**	**31/07/2019**

5. Chapter Five: Can Corruption Distress Research Productivity?

5.1 Abstract

Research productivity is a key output of innovation activities. For this reason, this study empirically examines the influences of corruption, trade openness and English language on innovation outputs in terms of research productivity, using mixed models. The results obtained showed an adverse relation between both trade openness and corruption and research productivity. The study result that both trade openness and corruption are adversely related to research productivity. However, the results also demonstrate that countries which have the English Language as an official language are more active in the research field in terms of citations Reflected by number of citations than those countries which where the English is not an official language. On the other hand, the results in terms of publications showed that countries with English as an official language are not necessarily publishing more than those where English is not an official language. However, the results also indicate that number of publications is not necessarily higher in the former countries than the latter. Thus, the governments should establish international universities, moreover, granting funds (R&D) in order to support the international collaboration which eventually can lift the research productivity sector.

Keywords: Research Productivity, English Language, Corruption, Trade Openness.

5.2 Introduction

The economic growth of any nation depends on three main factors, namely the accumulation of capital stock, labour —human capital— and technological advancement. Innovation and research are the main factors that undergird the lattermost. The significance of knowledge productivity —research productivity— is noticeably rising and it is considered to be a key indicator of the development of a nation, serving as an engine to drive economic growth (DeMaria, 2009; Meo et al., 2013). Furthermore, many researchers have determined that there is a direct relationship between research productivity with the economic development of nations (Meo et al., 2013).

Many countries depend mainly on physical resources to develop their economy, yet, diversification is the key to sustainability in this respect. As a result, most countries have started reducing their dependency on natural resources and shifted towards a knowledge-based economy. This is an expression coined to describe trends in advanced economies towards greater dependence on knowledge, information and high skill levels. Thus, there is an increasing need for ready access to all of these resources by business and public sectors (Co-operation and Development, 1997). In a knowledge-driven economy, economic development is related to technological competitiveness, which is, in turn, driven by science and scientific research. In fact, in a knowledge-based economy, scientific research plays an essential role in economic growth. Many countries have been allocating resources to the research sector to improve their research productivity level. Notably, South East Asian countries (ASEAN) member countries experienced remarkable continuous economic growth in recent years; this is because these countries have increased investment in science and technology (Nguyen and Pham, 2011). Furthermore, a few Asian countries have been observed to shift from dependent economy (natural resources, agriculture, and primary commodities) to a knowledge-based economy (Meo et al., 2013).

However, many factors have a positive impact on the level of research productivity, which, in turn, stimulates the economic growth of nations. For instance, spending on education and investing in the research and development sector are essential factors to produce a substantial amount of innovative research. (Macilwain, 2010). Although there is more than 50 years' scholarly work of public, academic research, there is still little systematic evidence on how such investments can lead to increased levels of scientific output, improved patenting and innovative output, and hence better economic performance (Crespi and Geuna, 2008). However, research information seeking behaviour is essential to the economic success of a country (Preis et al., 2012).

Despite research productivity having been defined by many researchers (Ramsden, 1994; Ramesh Babu and Singh, 1998; DeMaria, 2009; Abramo and D'Angelo, 2014; Gul *et al.*, 2015), all definitions agree that new knowledge is the production of research activity which results in the research productivity (Al-Ohali and Shin, 2013; Abramo and D'Angelo, 2014). Therefore, new knowledge production function has a multi-input and multi-output character (Abramo and D'Angelo, 2014).

Research productivity has been an increasingly growing field of study since the end of the last century, and many studies have been published in this area. For instance, some researchers studied the trend of the research productivity of collective nations or a specific country (Nguyen and Pham, 2011; H. Kim *et al.*, 2012; Sooryamoorthy, 2013; Cavacini, 2016; Barrot, 2017; Horta, 2018). On the other hand, other researchers have focused on investigating the factors that affect research productivity such as GDP, R&D, and the number of universities (Dundar and Lewis, 1998; Gonzalez-Brambila and Veloso, 2007; Meo *et al.*, 2013; Abramo and D'Angelo, 2014; Albert *et al.*, 2016; Siddiqi *et al.*, 2016; Barrot, 2017; Bonaccorsi and Secondi, 2017). However, these studies have neglected some other factors that might have an impact on the research productivity level such as having English as the official Language, precisely because most of the global journals and especially the top ranking ones are in English regardless of specialisation (King, 2004). The second factor to examine in this study is trade openness[43] — and exchanging knowledge is a form of trade. Although the influence of corruption on the innovation level in terms of articles published was investigated in Chapter 3 of this

[43] Trade openness is defined as exchanging goods and services between countries.

thesis, the results were insignificant, and this is mainly due to using insufficient data. Therefore, to explore this issue in a more comprehensive way, a more extensive dataset over a larger time scale in terms of documents and citations is being used. The current study attends to examining the impact of corruption, trade openness and English language on the research productivity level of culled nations.

Thus, the objective of this study is threefold. First, we investigate if having English as the official language has a direct impact on nations' level of research productivity using a cross-country dataset of 170 countries over the periods1996-2018. Second, we examine if trade openness has a direct impact on the research productivity of countries. Thirdly, we study and quantify the impact of corruption on the research productivity level of selected countries. Mixed methods are the appropriate model in this study to quantify the impact of English language and trade openness on innovation —that is research productivity. Furthermore, the results of this study are quite ambiguous: on the one hand they confirm that English as an official language gives countries the privilege to cite more because of most journals being in English —and English is the official language across the world, as it is the most spoken and global language (Northrup, 2013; Noack and Gamio, 2015)—. On the other, they reveal that English has nothing to do with the number of publications, and yet it still might be a reason to decrease the research productivity level in terms of number of documents published because most journals despite the level are in English. Furthermore, regarding trade openness, the results showed a surprising significant in that trade plays a constraint: trade openness hinders innovation in terms of research productivity. Moreover, the corruption factor results show that less corrupt countries are more likely to be innovative in terms of research productivity and conversely, more corrupt countries are less likely either to publish or cite.

Research productivity is a very recent and popular topic of measuring innovation by using it as a proxy. This study offers four unique contributions to the literature. Firstly, it seeks to contribute to the empirical literature of innovation especially in the scientific research productivity —science wealth, bibliometric science—, as it provides a cross country empirical analysis of how English Language plays a role in improving the research productivity of nations. To the best of the researcher's knowledge, this factor has not yet been studied in the context of English and research productivity using a larger scale of observations. Secondly, this paper adds to the strand of the literature by quantifying the impact of openness on the level of research productivity as a proxy for innovation. Thirdly, this study extends investigations of the relationship between corruption and research productivity and quantifies the effect level —in case it exists— consequently, it adds to corruption literature. Finally, it contributes to the bibliometric literature as we are using the rich panel data of 3124 observations for 170[44] countries for 23 years over the period of 1996-2018.

The rest of the study is organised as follows. The next section gives a brief explanation of the innovation in terms of research productivity according to previous theoretical and empirical studies. Section 4 explains the methodology, and it is followed by the description of the data and variables in section 5. Section 6 provides a comprehensive interpretation and analysis of the results along with a discussion of these. Section 7 provides the conclusion of the chapter, and finally, section 8 details the limitations of the research project and the avenues for future research.

5.3 Literature Review

Research productivity —such as patents, publications, citations— is the result of research activities which have been carried out using innovations inputs of R&D and researchers. Furthermore, research productivity or scientific output has a direct association with the economy of countries which are in the process of transforming into a knowledge based economy (Nguyen and Pham, 2011). Although researchers have a recent but growing interest to study the research productivity and its relevant issues or determinants, the literature in this field is not abundant. However, the current literature has investigated the trends and the determinants of research productivity at micro (K.-H. Kim, 2014) and macro levels (Meo *et al.*, 2013; Bentley, 2015).Countries share in research productivity is increasing yearly (Barrot, 2017). Yet, there is a noticeable difference of publications at individual level (Bentley, 2015).There are several determinants that have been used by researchers

[44] Some other researchers used a smaller scale of countries like Gul *et al.* (2015) who used 15 countries in the Middle East region

to address research productivity. For instance, investing in human capital — specifically investing in master and doctoral students — and granting governmental funds for research are the main drivers for enhancing research productivity (K.-H. Kim, 2014). Furthermore, investing in the R&D sectors and improving the quality of the universities along with increasing the quantity of universities are also important factors to improve the research productivity of nations (Kocher *et al.*, 2006; Meo *et al.*, 2013). Moreover, collaboration between universities/laboratories is a crucial factor to improve innovation outputs, specifically publications (Lee and Bozeman, 2005).

At the same time, however, the literature on research productivity in the Middle East and North Africa (MENA) region is relatively less abundant and it is not well documented (Waast and Rossi, 2010; Gul *et al.*, 2015). (Waast and Rossi, 2010) showed the trends and local shades of the scientific output (in terms of internationally recognized publications) in west Asia and North Africa. However, there are some recent studies which have been done in specific regions in the MENA region such as Noruzi and Abdekhoda (2014) who examined the performance of research level at universities in the Kurdistan of Iraq. Gul et al. (2015) evaluated the research productivity and performance of 15 countries in the Middle East Region. (Sarwar and Hassan, 2015) analyzed the research productivity in the MENA region and found that Iran and Turkey have the highest level of research productivity in the MENA region. Cavacini (2016) compared the scientific output of 16 countries in the Middle East during the period of 1996-2014 to 27 countries in West Europe and to the average world production, and analyzed data year by year in order to find trends (Cavacini, 2016). The scientific production landscape in the Middle East has been rapidly transforming over the last decades while this area has been in the international spotlight for regional conflicts. Recently, new countries from the Middle East gained significant share in terms of scientific contribution to the world, as they joined the world leading nations in the number of scientific documents produced and cited.

However, many studies which are in the research productivity field take into consideration the determinants which impact on the level of research productivity such as R&D expenditure (May, 1998; Meo *et al.*, 2013), GDP per Capita (Meo et al., 2013), size of university (Meo *et al.*, 2013; Bonaccorsi and Secondi, 2017), and collaborative research —international cooperation—(Lee and Bozeman, 2005; Sooryamoorthy, 2013; Sarwar and Hassan, 2015; Albert *et al.*, 2016).

5.3.1 Research Productivity Share (1996-2018)

The USA dominated this, being in first place for all years of the study period. Nevertheless, its share of the globally published documents decreases noticeably —it reaches 18% in 2018, as opposed to 32% in 1996—, and this is not because the USA does not publish, but because other countries —mainly China— are increasing their research activity. Figure (5-2) shows the share of the documents published for the period of 1996-2018 for selected countries, namely, the USA, UK, India and China. As mentioned above, the graph shows that the USA has the most significant share of documents published, yet its share decreased steadily over the same period, whereas China's share increased significantly. According to Scimago Journal & Country Rank, in the year 2018, almost 4 million articles have been published, with the USA contributing around 17% of the world's total. However, China's share of publications notably increased from 3% to 15% between 1996 and 2018, while the USA's share decreased from 32% to reach 17% over the same period. The possible cause of this fluctuation of research production in the total world share is that some developing countries are emerging in the research productivity area as they are moving toward the knowledge-based economy. Another possible reason might be that some countries are not concerned regarding the quality of the journal to publish and tends towards the quantity over quality of publications. Consequently, the share

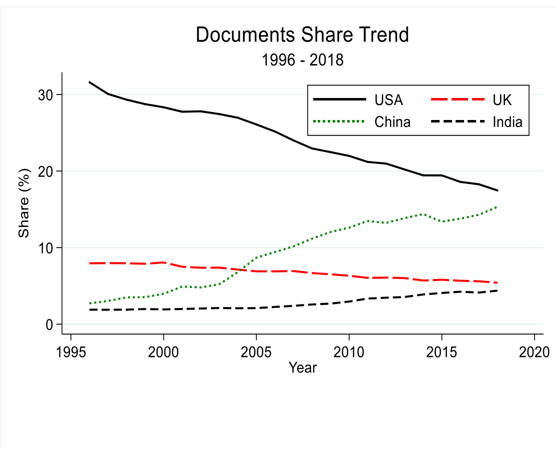

Figure 5-2.Documents Share trend
Source. Scimago Journal & Country Rank

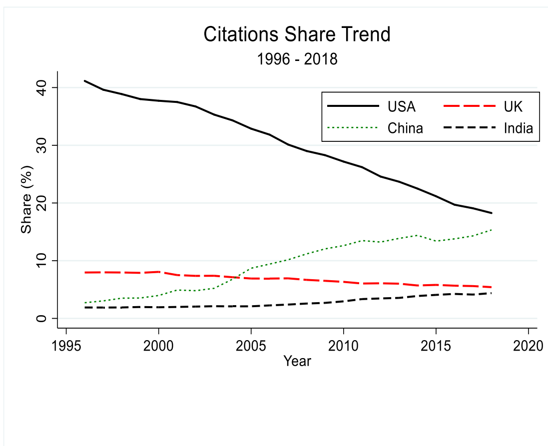

Figure 5-1.Citations Share trend
Source. Scimago Journal & Country Rank

of the citations fluctuates as well, as shown in Figure (5-1). According to Scimago Journal & Country Rank, the USA's share of global citations decreased drastically from 41% in 1996 to 18% in 2018. While China's citations share of the worldwide citations increased strikingly from 1% in 1996 to reach 14%.

5.4 Methodology

According to the main factors in this thesis, we carry out an analysis to examine the impact of trade openness along with corruption on the level of research productivity considered as a proxy for innovation. Due to the results of chapter three of this thesis — paper 1 titled "*Is corruption Detrimental to Innovation?*"—, that corruption has not impact on the innovation outputs specifically, has no impact on the articles published, therefore, we carried out this analysis for further research. In order to address the issues of investigating the relationship between the main factors and research productivity, we consider other variables that might influence research productivity[45]. Hence, we use unbalanced panel data for 170 countries over the period of 1996-2018.

The general panel model is given by equation (5-1).

$$Y_{it} = \alpha_i + \beta\, X_{it} + \mu_{it} \qquad (5\text{-}1)$$

where, *Y* signifies research productivity, represented by the number of documents, number of citations and citations per document. *X* is a vector that represents our main variables of the three models: English Language, Corruption and trade openness. Furthermore, it represents other exogenous variables, which are: R&D, GDP per Capita, country size, GDP, and year dummies. In this study, there are three models to be estimated, which are given as follows:

$$\begin{aligned} ldocs_{it} = \beta_i + \beta_{1it}\, L21_{1it} + \beta_{2it}\, corp_{2it} + \beta_{3it}\, trade_{3it} \\ + \beta_{4it}\, gdp_{4it} + \beta_{5it}\, capita_{5it} + \beta_{6it}\, pop_{6it} \\ + \beta_{7it}\, yr_{7it} + \mu_{it} \end{aligned} \qquad (5\text{-}2)$$

[45] The variables are elaborated in detail in section 5 of this chapter.

where *ldocs* signifies number of documents published (log form), *L21* denotes to the English language dummy variable, *corp* indicates to corruption, *trade* designates trade openness, *gdp* signifies gross domestic product (GDP), *capita* denotes to the GDP per capita, *pop* indicates to country size, *yr* denotes to the year dummies.

$$cites_{it} = \beta_i + \beta_{1it}\, L21_{1it} + \beta_{2it}\, corp_{2it} + \beta_{3it}\, trade_{3it} + \beta_{4it}\, gdp_{4it} + \beta_{5it}\, capita_{5it} + \beta_{6it}\, pop_{6it} + \beta_{7it}\, yr_{7it} + \mu_{it} \quad (5\text{-}3)$$

where *cites* signifies number of citations, *L21* denotes to the English language dummy variable, *corp* indicates to corruption, *trade* designates trade openness, *gdp* signifies gross domestic product (GDP), *capita* denotes to the GDP per capita, *pop* indicates to country size, *yr* denotes to the year dummies.

$$cpd_{it} = \beta_i + \beta_{1it}\, L21_{1it} + \beta_{2it}\, corp_{2it} + \beta_{3it}\, trade_{3it} + \beta_{4it}\, gdp_{4it} + \beta_{5it}\, capita_{5it} + \beta_{6it}\, pop_{6it} + \beta_{7it}\, yr_{7it} + \mu_{it} \quad (5\text{-}4)$$

where *cpd* signifies citations per document, *L21* denotes to the English language dummy variable, *corp* indicates to corruption, *trade* designates trade openness, *gdp* signifies gross domestic product (GDP), *capita* denotes to the GDP per capita, *pop* indicates to country size, *yr* denotes to the year dummies.

5.4.1 Mixed models (Hierarchical linear models)

Based on the discussion in the previous section, model (1) was derived, which is the panel data model to be estimated for country *i* at time *t*. In order to quantify the impact of the main variables on the level of research productivity, a multilevel analysis model is used, because it allows for studying effects that vary by country, whilst also estimating country level averages. Furthermore, this method is allowed for unbalanced data—which is the case of this paper—. Multilevel models are also known in the literature as mixed models and hierarchical linear models. Mixed effects linear regression is characterised as containing both fixed and random effects, and our Models (5-2), (5-3) and (5-4) contains both fixed and random effects, with the former being measured directly (slope is the same across entities). In regard to the random effects, which are measured indirectly, according to their estimated variance and covariance (random coefficients and random intercepts). The mixed model offers two key advantages: it makes the specification of the random-effects term easier, and representing a mixed-model with the model above generalises easily to more than one set of random effects. Multilevel mixed effects linear regression can be extended to a more than two-level model, but in this paper, a two-level model is used including random effects at the second level. The model can be written as:

$$y_{ab} = \alpha_1 + \overbrace{\alpha_2 x_{ab} +}^{\text{Fixed effects}} \overbrace{\vartheta_b^{(2)}}^{\text{Random effects}} + \omega_{ab} \tag{5-5}$$

Where *y* is the dependent variable represented by the research productivity which is expressed by three proxies:1) number of documents, 2) number of citations and, 3) citations per document. *x* is the independent variables of corruption, research & development expenditure, country size, gross domestic product, trade openness, English language and year dummies. *a* is an index for the observations (panel data, so each year has an observation), *b* is an index for the countries (which are clustered into 170 countries). $\boldsymbol{\vartheta_{bc}^{(2)}}$ is the random intercept for the countries *b*.

5.5 Variables Description and data source

This section presents the variables used in this paper, which consists of three sub-sections. The first sub-section discusses in detail both the dependent and independent variables and the logic theme behind them, including them in the model. This is followed by a brief description of the sample of the study and the sources of the data. The third sub-section discusses the stationarity level of all variables using the unit root test. `

5.5.1 The Variables

5.5.1.1 The dependent variable

Research productivity has been used by many researchers in numerous instances of the literature as the dependent variable for different purposes. Research productivity is measured using different bibliometric indicators, for instance, Dundar and Lewis (1998) measured research productivity as"the ratio of total publications to a number of program faculty". However, the most common bibliometric indicator for research productivity is the number of published documents, and it is a popular approach for measuring publication productivity (King, 2004; Meo *et al.*, 2013; Albert *et al.*, 2016; Horta, 2018). In this study, we are using three bibliometric indictors representing research productivity, which are the number of documents, the number of citations and citation per document —we are using three different indicators for accurate and valid results. These variables are the dependent variables in this study, where the data for those variables has been extracted from the Scimago Journal & Country Rank, and are derived from the Scopus for 23 years (1996-2018). The dependent variables are elaborated below in detail.

1. Documents

The documents variable is measured as the number of published documents per country per year in the log form, it is usually called the country's scientific output and this variable represents research productivity (King, 2004; Zavadskas *et al.*, 2011; Meo *et al.*, 2013; Noruzi and Abdekhoda, 2014; Gul *et al.*, 2015; Cavacini, 2016; Barrot, 2017).

2. Citations

The number of citations are our second proxy for the level of the research productivity of nations (King, 2004; Zavadskas *et al.*, 2011; Noruzi and Abdekhoda, 2014; Gul *et al.*, 2015; Cavacini, 2016; Barrot, 2017). It is measured as "a number by the documents published during the source year to documents published during the same year" by Scimago Journal & Country Rank organization.

3. *Citation per document*

Citations per document are calculated as "the average of the citations per document during the source year to documents published during the same year". It is used by Meo et al. (2013), Gul et al. (2015), Cavacini (2016) and Barrot (2017) as a proxy to represent the level of research productivity.

5.5.1.2 The independent variables

A number of factors are capable of influencing the research productivity of any country. According to DeMaria (2009), the most obvious and probably most important among these factors are the economic status, wealth and population size of a country. Furthermore, Brew *et al.* (2016) have argued that numerous studies have been carried out to examine factors that contribute to research productivity. In our study, in addition to our principal factor, language, we control for other variables that are expected to be important factors to research productivity. The choice of explanatory variables is inspired by the related empirical and theoretical literature and the availability of data. A detailed explanation for the chosen variables is elaborated below.

1. *English Language*

English is the most spoken language in the world in terms of countries which consider it as one of the official languages in the country (Montgomery, 2013). The initial assumption is that English language is a barrier to the level of countries' research productivity; keeping in mind that most of the journals in all fields are in English. Therefore, there is a need to empirically investigate if English hinders the increase of research productivity levels. The main reason for adding this variable in all models is to quantify the impact of the English language (as an official language) on the level of the research productivity of nations. English language has been added as a dummy variable in the three models (i.e. if English is an official language in a country=1, Otherwise 0). The argument is that the countries where English is an official language have higher research productivity levels than the countries where English is not an official language (DeMaria, 2009; Montgomery, 2013; Bentley, 2015).

2. Trade openness

Trade is expressed as a proportion —percentage— of a country's GDP and trade in its general meaning is about importing and exporting goods and services between nations, therefore, the argument is that the countries which are more open to trade have a better chance to have researched or published documents than countries which are less open to trade, meaning that trade has a positive impact on the research productivity level of countries.

3. Corruption

We are controlling corruption, the main variable in this thesis as a proxy for the relative performance of governmental institutions (Mauro, 1995). We argue that corruption has a negative impact on the level of research productivity of countries: countries with more corruption have less research specifically due to corruption. We are using the Corruption Perception Index (CPI) as the proxy for the corruption level of countries as it is the most accepted measure of corruption (Mo, 2001; Varsakelis, 2006; Veracierto, 2008; Lau *et al.*, 2015; Huang, 2016).

Transparency International (TI) is the leading organisation to fight against corruption, and it is the organisation which pointed to collecting CPI data. However, TI measures the perceptions of corruption on a scale of 0 to 100, with 0 indicating the highest level of corruption and 100 indicating the lowest. However, for this paper and to avoid any confusion, we reversed the scale so that 0 indicates the lowest level of corruption (clean countries) and 100 indicates the highest level of corruption (highly corrupt countries).

4. Research & Development expenditure

Research & Development expenditure (R&D) is used as a proxy for capital inputs which are devoted to innovative activities, and it is measured as a share of the GDP (Varsakelis, 2006). Furthermore, by using overall R&D expenditure, we implicitly assume that the same proportion of such spending is devoted to economics in each country (Kocher et al., 2006). Research and development expenditure, which is defined as the current and capital expenditures (both public and private) on creative work, is undertaken systematically to increase knowledge. The R&D expenditure variable has been added in all three models as a proportion of GDP. The argument is that the countries which invest more in the public or private R&D sector are more likely to have a high level of research production (Meo et al., 2013). More R&D expenditures (input) means more published documents. The R&D aspect reflects the extent to which a country allocates resources for growing the overall stock of knowledge.

5. Country Size

Country size is the proxy for the total population; we argue that countries with a larger population size can yield a larger pool of individuals with interest and talent in the scientific investigation as they have more opportunities for a higher level of research productivity (DeMaria, 2009).

6. Gross Domestic Product

Gross Domestic Product (GDP) is the economic growth measured in terms of an increase in the size of a country's economy. It is the main indicator used to gauge the strength of a country's economy. The argument is that the growing GDP has a positive impact on the level of the research productivity of nations. It is used as a scale of economy for comparison purposes. The argument is that the growing GDP has a positive impact on the level of the research productivity of nations. It is used as a scale of economy for comparison purposes. Meo et al. (2013) are one of the researchers who used this variable in the same context as ours. However, we argue that the GDP has a positive impact on the level of research productivity of nations.

7. The year dummy (1996-2015)

1996 is omitted from the regressions to avoid the dummy variable trap. The year dummies have been added to capture the influence of the aggregate trends (citations) due to the time series. Additionally, the time year dummies are added in order for the cross country regression not to be influenced by the aggregate trends. The research productivity in the models changes over time for the reasons below:

1. In terms of citations, the more recent the journals, the fewer chances the journals have to gain citations, which is termed the pure time effect;

2. Many countries have been changing in recent years, particularly in the developing world. They have simply been getting better at research, and hence, more recent papers are of a higher quality;

3. Fewer years are being cited, for researchers prefer to cite the most recent documents rather than old ones, and hence, there is a bias for more recent work to be cited;

4. More journals are published and hence more papers for citation, for instance, the American Journal of Economics used to come out three times a year, while now it has four issues.

5.5.2 The sample

The data which we are using to run the regression is an unbalanced panel dataset. It is unbalanced because the sources which we extracted the data from do not have the full dataset. The World Bank is the main source for the data in this paper. Nevertheless, the World Bank has reported several reasons why data is not available for certain indicators for certain countries and certain years. Firstly, certain indicators are derived from sporadic surveys and are only available for some years. Secondly, certain data sets or indicators are only available from the year they were initiated. Thirdly, some countries do not regularly report data due to conflict, lack of statistical capacity, or other reasons. Moreover, fourthly, certain countries do not have data for earlier years simply because they did not exist. Because we have missing observations for certain time periods of certain countries, we are using the annual data of 170 countries for the period of 1996-2018.

Table (5-1) shows a summary of the variables and the data source. Table (5-2) describes the summary statistics of the dependent variables and the explanatory variables, which include their number of observations, mean, standard deviation, minimal value and maximum value. Table (5-3) shows the countries which are included in the regression, and they are divided region-wise according to the World Bank division.

Table 5-1. The Glossary of Variables

Symbol of Variables		Full Variable Name	Variable definition	Source of the data	Measurement Unit
Dependent variables	docs	Number of Documents	absolute number of published documents per country	Scimago Journal & country Rank	Log Form
	cites	Number of Citations	absolute number of citations by the documents published	Scimago Journal & country Rank	Absolute Number
	cpd	Citations Per Document	It average of the citations per document during the source year to documents published during the same year	Scimago Journal & country Rank	Absolute number
Independent variables	L21	English Language	(i.e. if English is an official language in a country=1, Otherwise 0)	Central Intelligence Agency Fact Book	1,0
	trade	Trade openness	value of exports plus the value of imports (% of GDP)	World Bank	%of GDP
	corp	Corruption Perception Index	Corruption Perception Index (0 indicates clean countries, 100 indicates corrupt countries)	Transparency International organization	index
	rd	Research & Development	Research & development Expenditure (%of GDP)	World Bank	%of GDP
	pop	Country size	all the residents in the country regardless of legal status or citizenship	World Bank	Absolute number
	gdp	Gross Domestic Product, ppp	The sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.	World Bank	US $
	capita	GDP per Capita, ppp	GDP per capita is gross domestic product divided by midyear population.	World Bank	US $
	d1996-d2018	Year dummy (1996-2018)			

Table 5-2. Summary of the statistics results

Variables			Observations	Mean	Standard Deviation	Minimum	Maximum
Dependent Variables	Log Documents		4,648	5.945289	2.849329	0	13.43511
	Citations Per Document		4,648	17.9782	15.09425	0	471.8
	Citations (,000,000)		4,648	.2058622	1.072052	0	18.09516
Independent Variables	English Language		4,807	0.3062201	0.4609702	0	1
	Trade Openness		4,692	75.62668	61.64626	0	860.8
	Corruption		3,419	59.75984	23.47685	0	100
	Research & Development		4,692	0.3506888	0.7260307	0	4.42859
	Country Size		4,692	30.8036	124.2697	0	1386.395
	Gross Domestic Product (,000,000,000)		4,692	381.2237	1428.524	0	21223.92
	GDP per Capita		4,488	15.55132	19.61225	0	135.3188
	Year Dummy	1996	4,807	0.0434783	0.2039523	0	1
		1997	4,807	0.0434783	0.2039523	0	1
		1998	4,807	0.0434783	0.2039523	0	1
		1999	4,807	0.0434783	0.2039523	0	1
		2000	4,807	0.0434783	0.2039523	0	1
		2001	4,807	0.0434783	0.2039523	0	1
		2002	4,807	0.0434783	0.2039523	0	1
		2003	4,807	0.0434783	0.2039523	0	1
		2004	4,807	0.0434783	0.2039523	0	1
		2005	4,807	0.0434783	0.2039523	0	1
		2006	4,807	0.0434783	0.2039523	0	1
		2007	4,807	0.0434783	0.2039523	0	1
		2008	4,807	0.0434783	0.2039523	0	1
		2009	4,807	0.0434783	0.2039523	0	1
		2010	4,807	0.0434783	0.2039523	0	1
		2011	4,807	0.0434783	0.2039523	0	1
		2012	4,807	0.0434783	0.2039523	0	1
		2013	4,807	0.0434783	0.2039523	0	1
		2014	4,807	0.0434783	0.2039523	0	1
		2015	4,807	0.0434783	0.2039523	0	1
		2016	4,807	0.0434783	0.2039523	0	1
		2017	4,807	0.0434783	0.2039523	0	1
		2018	4,807	0.0434783	0.2039523	0	1

Notes:

1) The summary of statistics is provided based on the time period of 1996 to 2018 for 170 countries worldwide.

2) The dataset used in this paper is unbalanced because there are some gaps in year for some countries due to the unavailability of the data.

Table 5-3. List of countries included in this study

Europe & Central Asia	Sub-Saharan Africa	Latin America & Caribbean	East Asia & Pacific	Middle East & North Africa	South Asia	North America
Albania	Angola	Argentina	Australia	Algeria	Afghanistan	Canada
Armenia	Benin	Bahamas, The	Brunei Darussalam	Bahrain	Bangladesh	United States
Austria	Botswana	Barbados	Cambodia	Djibouti	Bhutan	
Azerbaijan	Burkina Faso	Bolivia	China	Egypt, Arab Rep.	India	
Belarus	Burundi	Brazil	Hong Kong SAR, China	Iran, Islamic Rep.	Maldives	
Belgium	Cabo Verde	Chile	Indonesia	Iraq	Nepal	
Bosnia and Herzegovina	Cameroon	Colombia	Japan	Israel	Pakistan	
Bulgaria	Central African Republic	Costa Rica	Korea, Rep.	Jordan	Sri Lanka	
Croatia	Chad	Dominica	Lao PDR	Kuwait		
Cyprus	Comoros	Dominican Republic	Malaysia	Lebanon		
Czech Republic	Congo, Dem. Rep.	Ecuador	Mongolia	Libya		
Denmark	Congo, Rep.	El Salvador	Myanmar	Malta		
Estonia	Equatorial Guinea	Grenada	New Zealand	Morocco		
Finland	Eritrea	Guatemala	Papua New Guinea	Oman		
France	Ethiopia	Guyana	Philippines	Qatar		
Georgia	Gabon	Haiti	Singapore	Saudi Arabia		
Germany	Gambia, The	Honduras	Solomon Islands	Tunisia		
Greece	Ghana	Jamaica	Thailand	United Arab Emirates		
Hungary	Guinea	Mexico	Vanuatu	Yemen, Rep.		
Iceland	Guinea-Bissau	Nicaragua	Vietnam			
Ireland	Kenya	Panama	Timor-Leste			
Italy	Lesotho	Paraguay				
Kazakhstan	Liberia	Peru				
Kyrgyz Republic	Madagascar	Puerto Rico				
Latvia	Malawi	St. Lucia				
Lithuania	Mali	St. Vincent and the Grenadines				
Luxembourg	Mauritania	Suriname				
Moldova	Mauritius	Trinidad and Tobago				
Montenegro	Mozambique	Uruguay				
Netherlands	Namibia	Venezuela, RB				
Norway	Niger					
Poland	Nigeria					
Portugal	Rwanda					
Romania	Senegal					
Russian Federation	Seychelles					
Serbia	Sierra Leone					
Slovak Republic	South Africa					
Slovenia	Sudan					
Spain	Tanzania					
Sweden	Togo					
Switzerland	Uganda					
Tajikistan	Zambia					
Turkey	Zimbabwe					
Turkmenistan						
Ukraine						
United Kingdom						
Uzbekistan						

5.5.3 Unit root tests

The dataset which we are using is an unbalanced panel dataset. The appropriate unit root test to be used is the Fisher-type test because it does not require strongly balanced data, and the individual's series can have gaps (Baltagi, 2008; p.244-245). Therefore, we are using the Fisher-type test (Fisher, 1932) using ADF and PP tests (Maddala and Wu, 1999; Choi, 2001). Furthermore, the lag lengths of the individual augmented Dicky-Fuller tests are allowed to differ. Fisher-type tests were used to test the null hypothesis, which represents the presence of an "individual unit root". The Fisher-type test uses p-value from unit root tests for each country i. The test is asymptotically chi-square distributed with 2N degrees of freedom, $T_i \underset{i}{\rightarrow} \infty \; for\; finite\; N,$ (Nell and Zimmermann, 2011). The formula of the test is expressed as follows:

$$\boldsymbol{P = -2\sum_{i=1}^{N} ln\, p_i} \qquad (3\text{-}14) \qquad (5\text{-}6)$$

Furthermore, the results show that all variables are stationary. Table (5-4) shows the results of the unit root for all variables. It can be concluded from these results that the null hypothesis is strongly rejected. Thus, it can be assumed that all the series are stationary at the same level (no unit root).

Table 5-4. Unit Root results

The variables	Individual intercept/trend/none	ADF- Fisher Chi Square			PP-Fisher Chi-Square		
		Observations	Cross sections	t-statistic	Observations	Cross section	t-Statistic
Log Documents	Individual effects, individual linear trends	4246	206	825.382***	4378	206	830.361***
Citations	Individual effects, individual linear trends	4215	206	507.221***	4378	206	511.949***
Citations Per Document	Individual effects, individual linear trends	4220	206	1139.58***	4378	206	1264.16***
Trade openness	none	4158	191	518.357***	4202	191	496.8***
Corruption	Individual effects, individual linear trends	2959	174	1038.98***	3122	174	1190.63***
Research & Development	Individual effects, individual linear trends	2957	139	560.01***	3058	139	722.474***
Country Size	none	4106	194	738.907***	4268	194	455.433***
Gross Domestic Product	none	3998	186	625.489***	4092	186	408.348*
GDP per Capita	Individual effects, individual linear trends	3775	187	810.612***	3927	187	420.813**
legend: * p<0.1;** p<0.05; *** p<0.01							
Ho: All panels contain unit roots							
Ha: At least one panel is stationary							

5.6 Empirical Results & Discussion

This section is divided into three sub-sections: the first one presents an overview of the global research productivity trend, while the second sub-section presents the national level results for 170 countries over the period of 1996-2018. The last subsection discusses the results of the three models comprehensively.

5.6.1 World's Research Productivity Trend

The trend of the research productivity across the world of all nations cumulatively has been significantly growing in terms of the number of documents published. According, to the Scimago Journal & Country Rank, the volume of documents published has been more than double—the number of published documents has increased by 246% over the last 23 years, between the periods of 1996-2018. This is because many countries have been changing over time, particularly in the developing world. They have been getting better and hence more recent papers will be better. On the other hand, global citations have decreased by more than 90% within the same period, which might be because of the pure time effect: the more recent the journal, the less chance it has to gain citations. Nevertheless, it is worth mentioning the case of China, as it is a developing and growing economy whose share to the globally published documents has increased drastically by 15% between 1996 and 2018. Consequently, in terms of the number of citations, its share in terms of citations is 14% over the same period. Figure (5-3) shows the trend of Global research productivity from 1996-2018.

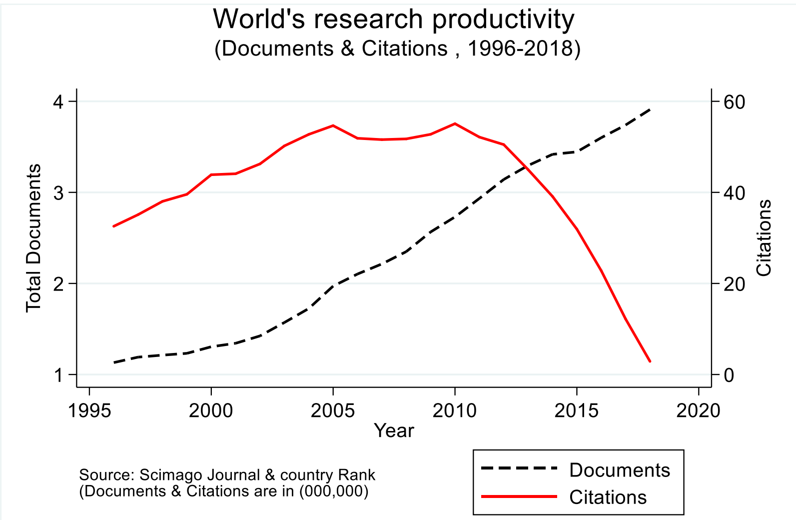

Figure 5-3. World Research Productivity Growth

Figure (5-4) shows the intensity of the document vs, citations intensity over 23 years, where document and citation intensity are measured as the ratio of the publications (volume of documents) and citation to the national GDP. Figure (5-5) exhibits the relationship between documents and citations (in log form), which shows a linear relationship between the two variables. While the USA is ranked in the first place, with the highest share of publications, when the intensity of the document vs citations intensity is measured, Iceland is top-ranked.

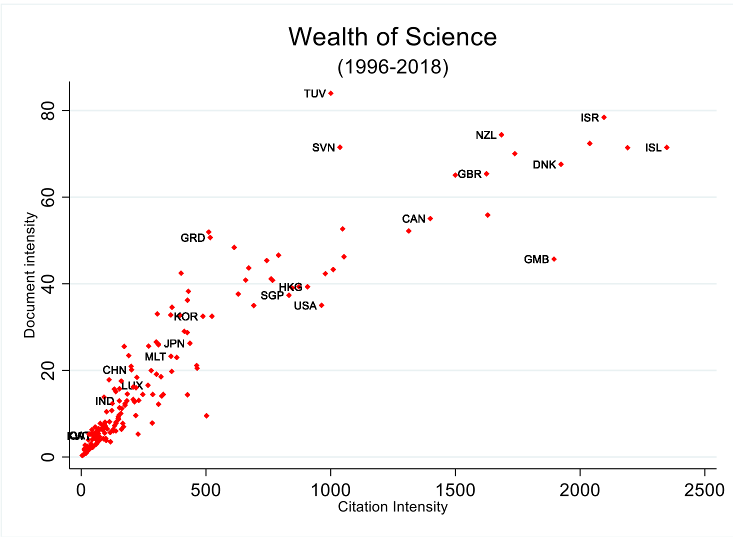

Figure 5-4.Documents Intensity vs. Citations intensity over the period (1996-2018).
Source: Scimago Journal & Country Rank

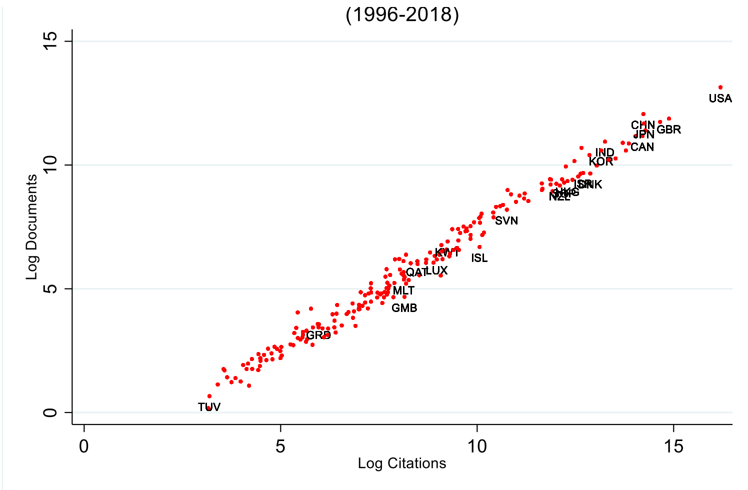

Figure 5-5. Documents vs. Citations over the period (1996-2018).
Source: Scimago Journal & Country Rank

5.6.2 Panel Data Results

Mixed-effects regression is used to run the regressions with restrict to values of GDP per capita and corruption bigger than zero, because there are some missing values that STATA, the program we use considers as zero even though they are not. Table (5-5) shows the results of the regressions analysis. As mentioned above, the main variables in this paper are corruption, English language and trade openness, for which the question of whether there is a direct relationship of these variables with the research productivity level is assessed. These variables show significance in all three models.

Table 5-5. Empirical Results of regression analysis- 170 countries

The Variables	Log. Documents	Citations (,000,000)	Citations Per Document
English Language	-0.499*** (-7.377)	0.281*** (7.639)	2.868*** (7.225)
Trade Openness	-0.005*** (-8.005)	-0.001*** (-3.991)	-0.008*** (-3.116)
Corruption	-0.029*** (-13.318)	-0.004*** (-5.454)	-0.127*** (-10.739)
R&D	0.984*** (19.244)	0.108*** (2.862)	0.879*** (4.122)
Country Size	0.003*** (15.164)	-0.004*** (-7.78)	-0.008*** (-11.938)
GDP (,000,000,000)	0*** (7.541)	0.001*** (9.816)	0 (1.288)
GDP per Capita	0.022*** (7.868)	-0.001 (-1.434)	-0.044*** (-4.906)
1997	-0.054 (-0.308)	-0.003 (-0.052)	0.364 (0.35)
1998	0.256 (1.265)	-0.062 (-0.59)	-0.192 (-0.176)
1999	0.099 (0.507)	-0.065 (-0.708)	0.515 (0.456)
2000	0.288 (1.434)	-0.026 (-0.238)	1.587 (1.322)
2001	0.132 (0.657)	-0.048 (-0.455)	1.943 (1.529)
2002	0.114 (0.587)	-0.036 (-0.362)	1.606 (1.281)
2003	-0.044 (-0.238)	-0.038 (-0.441)	1.49 (1.295)
2004	-0.144 (-0.789)	-0.042 (-0.517)	1.448 (1.342)

The Variables	Log. Documents	Citations (,000,000)	Citations Per Document
2005	-0.129 (-0.708)	-0.047 (-0.619)	-0.16 (-0.158)
2006	-0.115 (-0.638)	-0.085 (-1.233)	-1.081 (-0.965)
2007	-0.203 (-1.118)	-0.106 (-1.648)	-2.497*** (-2.275)
2008	-0.167 (-0.907)	-0.118* (-1.868)	-3.467*** (-3.552)
2009	-0.081 (-0.443)	-0.115* (-1.822)	-4.684*** (-4.596)
2010	0.091 (0.508)	-0.115* (-1.794)	-3.761*** (-3.713)
2011	0.098 (0.535)	-0.146*** (-2.375)	-6.769*** (-7.728)
2012	0.214 (1.168)	-0.176*** (-2.805)	-6.838*** (-6.384)
2013	0.271 (1.501)	-0.226*** (-3.543)	-10.737*** (-12.851)
2014	0.403*** (2.247)	-0.28*** (-4.031)	-10.864*** (-11.38)
2015	0.426*** (2.39)	-0.346*** (-4.414)	-11.518*** (-10.769)
2016	0.449*** (2.469)	-0.4*** (-4.551)	-14.96*** (-15.507)
2017	0.894*** (4.584)	-0.439*** (-5.41)	-18.617*** (-21.986)
Constant	7.975*** (32.389)	0.416*** (4.32)	30.581*** (23.16)
Random Effects Constant	0.471*** (40.721)	-0.411*** (-5.115)	2.119*** (55.474)
Number of Observations	3124	3124	3124
Log Likelihood	-5903.02	-3149.55	-1.11E+04
Degrees of Freedom	28	28	28

t-statistics is reported in the parentheses ( ).
Robust standard errors have been used. legend: * p<0.1;** p<0.05; *** p<0.01

5.6.2.1 Number of documents

Table (5-5) shows the results for the Model (5-2), where the number of documents is the dependent variable. Our main variable in this study is the English Language; we argue that research productivity is directly affected by the language meaning that countries with English as an official language are wealthier scientifically. The results show that English has nothing to do with the number of documents published per country, but the decreasing of the number of documents published because English is not necessarily the reason for countries to publish. For instance, even though China is growing outstandingly in terms of publications, English is not an official language. This increase is might be due to China having its own journals in Chinese and the reason for the bias might be that the model disregards the strength of the journals: as we included all the publications irrespective of the place of the publications. Additionally, Bentley (2015) findings confirm that countries where people do not speak English prefer to publish in the domestic journals. In regard to, trade openness, which is about exchange of goods and services between countries, this has a negative impact on the research productivity of countries as shown in Table (5-5). When the country's trade increases by 1%, the research productivity in terms of documents will go down by 0.0052 percentage points. Consequently, trade has no advantage in improving the research productivity, yet, it slows it down. Regarding corruption, the main variable in this thesis, the results reveal that corrupt countries are less likely to publish documents and be productive in research. The cleaner countries, —mainly developed countries, are more likely to be rich in science as they publish more— Furthermore, this result is consistent with the R&D expenditures where the result indicates that countries investing a fine proportion of their GDP in the R&D sector are more likely to publish as those resources are going into the research sector where publications are the main concern. Regarding the economy scale variable, GDP, where the result indicates that the countries with high GDP are more likely to publish, if the GDP increases by one percentage point, the publication would increase by 0.0247 percentage points.

5.6.2.2 Number of citations

The results where the number of citations is the dependent variable, are shown in table (5-5). In reference to the English language, it has a positive significant impact on the research productivity of nations as the countries with English as an official language are more likely to cite which eventually increases the research productivity and consequently improves the economic growth of countries. Regarding the trade openness variable, the results indicate that the number of citations is negatively associated with trade openness. Countries which are more open to trade are less likely to cite or have more citations, and less likely to do research. Furthermore, the main factor in this thesis —Corruption—reveals that more corrupt countries are less likely to do research, consequently they tend to cite less: because they produce fewer documents, they are less likely to cite compared to countries which focus on research and which are mainly clean countries. The R&D variable shows that the countries which tend to invest a fine portion of their GDP in the R&D sector are more likely to do research, which means they tend to cite more. The economy scale variable, GDP, shows a positive association with the number of citations; when the GDP increases by 1 billion US dollar, the number of citations increases by 754 citations.

5.6.2.3 Citations per document

We added this model as we want accurate and valid results. Therefore, to check consistency, we run the same regression using a different dependent variable, and, the results are shown in the Table (5-5). Our main variable, the English Language, shows a positively significant relationship with the dependent variable: countries with English as an official Language are more likely to have citations per document. On the other hand, the results regarding trade openness indicate that trade is not good for research. Trade has a negatively significant impact on the citations per document, meaning that the countries which are more open to trade are less likely to cite. Results regarding corruption are consistent with the Model (5-2) and (5-3), indicating that it has a negative impact on research productivity: countries which tend to be more corrupt, are less likely to do research and vice versa.

5.6.3 Discussion

In sum, the three models show the significance of the main variables in this study: corruption, English language and trade openness. The other variables such as R&D, GDP, country size and GDP per capita show significance in different levels with both positive and negative impacts.

They start with our main variable, English, — where the results show a miscellaneous significant direct relationship in all three models. Countries which have the English language as an official language have an advantage over the countries which do not in terms of a number of citations, yet they are less likely to publish documents. Hence, those countries are more likely to be more innovative because English is the global language of research (DeMaria, 2009). Yet, Bentley (2015) has found that publishing in the English language is dominant but not exclusive as our results showed. On the other hand, trade openness shows significance in all the three models with adverse impact on the level of research productivity: countries which are more likely to open to the rest of the world via trade are less likely to do research (i.e. publish or cite). Therefore, as per our results, trade is bad for the research productivity of nations. Figure (5-6) shows the relationship between research productivity intensity (in terms of documents & citations). The figure shows that in countries open to trade such as Singapore, Hong Kong and Luxembourg the research productivity level is not quite parallel to their openness for trade. In contrast, countries like the USA and the UK which are less open to trade compared with the previous countries, have a better research productivity level. This can be explained by the suggestion that countries with better research are focusing on investing in research inside the country rather than investing in other countries, and this will result in more publications. Countries with less trade have a better research productivity level than the countries which are more open to a trade.

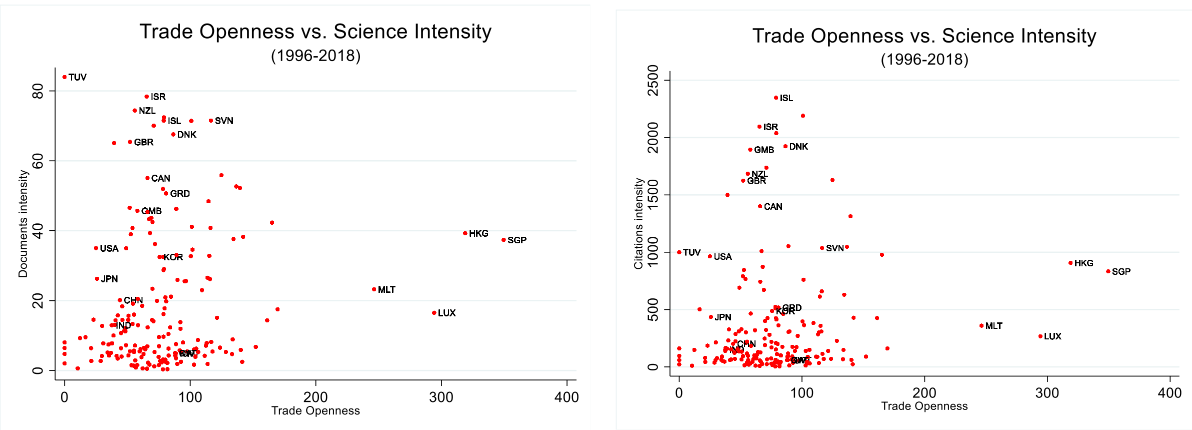

Figure 5-6. The relationship between Research productivity intensity and trade openness. Source. Scimago Journal & Country Rank and World Bank

The corruption variable which we added in the three models as a proxy for the relative performance of the governmental institutions (Mauro, 1995) shows a significant direct impact on the research productivity level of the nations in all the models. The results reveal that clean countries, less corrupt ones, are more likely to have better research productivity than highly corrupt countries because clean countries are focusing on public interest rather than on self-interest. Consequently, countries which are more likely to be corrupt are less likely to produce science. Figure (5-7) shows the relationship between research productivity and corruption. The results and Figure (5-7) are consistent, whereby the clean countries are publishing relatively more documents than the corrupt ones. In terms of citation intensity, the Gambia, is a good example with a high corruption level along with noticeable citations.

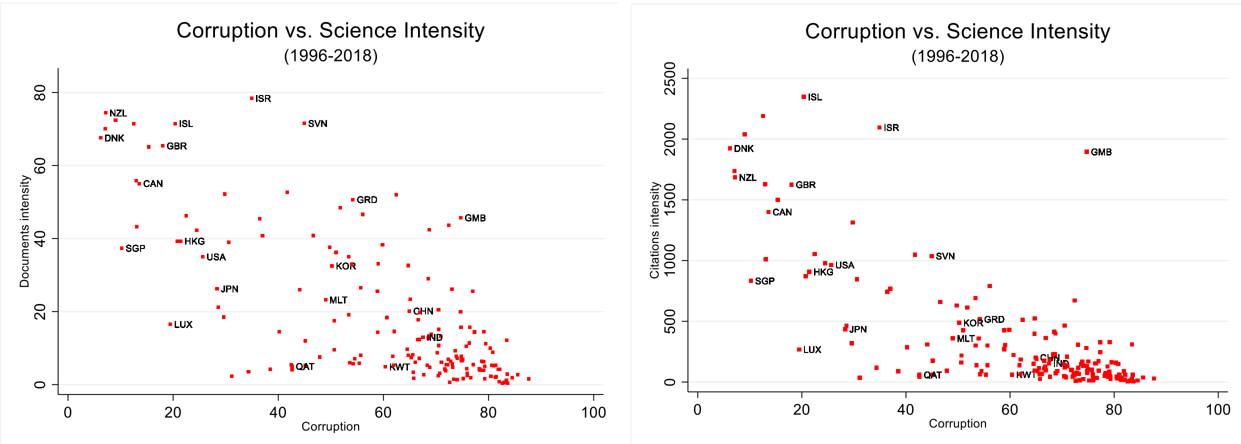

Figure 5-7. The relationship between Research productivity intensity and Corruption. Source. Scimago Journal & Country Rank and Transparency International

R&D expenditure is used as a proxy for capital inputs which are devoted to innovative activities, and it is measured as a share of the GDP. By using overall R&D expenditure, we implicitly assume that the same proportion of such spending is devoted to economics in each country (Kocher et al., 2006). The outcomes of the regression show that there is a direct association between R&D and research production: countries which invest more in the R&D sector, are more likely to be more innovative in research (Varsakelis, 2006; Larsen et al., 2008; Meo et al., 2013). Figure (5-8) shows the relationship between research productivity (documents and citation intensity) and R&D as a share of GDP. The illustration (5-8) shows a quite interesting relationship between the two factors; for instance, South

Korea and Japan have been investing a considerable proportion of their GDP in the R&D sector and yet their number of documents and citations are not commensurate with this. The main reason for South Korea investing a considerable proportion of its GDP in the R&D sector is that it strives to transform itself into a knowledge-based economy. It is one of the best examples of an economy that has become knowledge-based within less than 60 years.

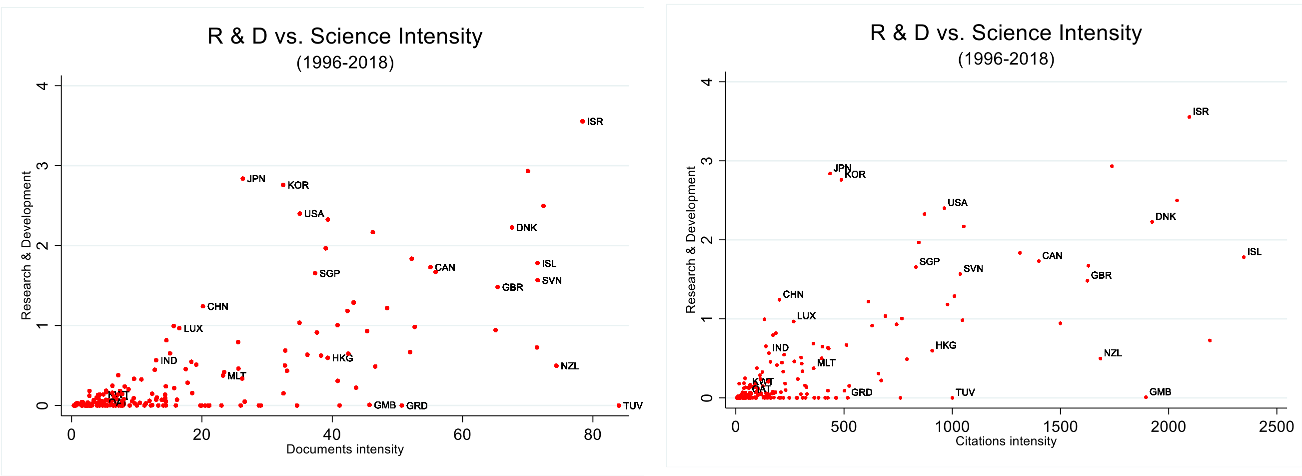

Figure 5-8. The relationship between Research productivity intensity and Research & Development. Source. Scimago Journal & Country Rank and World Bank

Country Size is measured in terms of the total population. We argue that the countries with more population have the opportunity to have better research productivity, as DeMaria (2009) argued that greater population would yield a larger pool of individuals with an interest and talent in scientific investigation, meaning that the pool of the people who work in the research sector will increase. Our results are consistent with DeMaria (2009), as the countries with more population tend to publish more, and the reason for this might be that more people means more opportunities to work in research, which consequently can yield more publications. Citations show a contrary association, whereby countries with more population are less likely to have better research productivity in terms of citations, which might be because of pure time effects.

The economy scale is represented in the GDP and is the main indicator used to gauge the strength of a country's economy. The results show a direct positive association between GDP and research productivity: countries with a higher GDP are more likely to have better research productivity. We added GDP per capita in three documents to check its impacts on the research productivity of nations and the results show an inverse relationship between research productivity that is citations per document. Countries with high GDP per capita have less research productivity. However, Meo *et al.* (2013) have found that GDP per capita has no association with research productivity.

Furthermore, Figure (5-9) shows a comparison between economic intensity (GDP per capita) to the research productivity intensity. The figure shows that there is no logical relationship between wealth intensity and research productivity intensity. For instance, Qatar and Kuwait have the highest GDP per Capita in the world yet neither have not have remarkable research productivity. Contrarily, The Gambia and Grenada have the lowest GDP per capita in the world and yet their research productivity level is remarkably high. It can be concluded that there is no association between GDP per capita and research productivity (Meo et al., 2013).

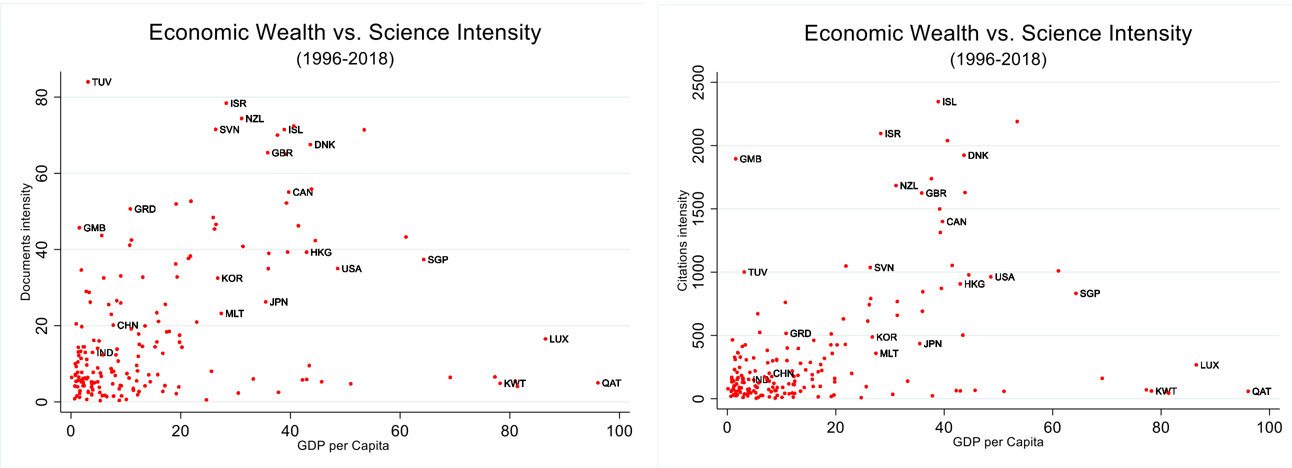

Figure 5-9. The relationship between Research productivity intensity and Wealth Intensity (GDP per Capita). Source. Scimago Journal & Country Rank and World Bank

5.7 Conclusion

This study has presented the impact of trade openness, English language and corruption factors on research productivity in terms of the number of documents and citations for 170 countries during the past 23 years by adopting the mixed methods of Hierarchical linear models. The empirical evidence reveals that both trade openness and corruption adversely affect research productivity. However, the results show that publications produced by countries with English as an official language are more cited than those where English is not an official language. This is firstly because English is an international language which makes research more visible to the world and secondly, most top-ranking journals are in English. Nevertheless, our findings reveal that this is not proportional to the number of publications produced by those countries, which means that countries with English as an official language do not necessarily tend to publish more documents. This might be due to the fact that these countries publish in domestic journals which are not necessarily in English. In conclusion, countries might be focusing on the quantity of published documents rather than their quality.

In light of the empirical evidence, we suggest some policies in order to improve the research sector in nations as follows. First, the researchers or institutions could translate the local published documents into English in this way, because English is the global language (Northrup, 2013), the local piece of work can be globally exposed. Second, governments should stress the importance of the research sector in economic and social development (Meo *et al.*, 2013) by establishing international universities, supporting international collaboration and increasing grants dedicated to research thus increasing R&D funds. Third, governments must highlight policies which can help to boost the research culture in countries.

5.8 Limitations and Future Research Directions

Some of the findings in this study shed additional light on the results of previous literature, while others are unique to the literature. While this work provides some interesting insights and ideas for future work in this strain, it has some limitations. One limitation is that this study might be more specific, as we can compare the research productivity using the same controlled variables using regions, or economy type or income levels. Furthermore, this study could be extended regionally or in terms of specialisation because those kinds of studies provide a comprehensive understanding of the distribution of research performance and productivity.

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VI. Chapter Six: Common Conclusion and Policy Implications.

This thesis has presented three empirical studies to explore the effects of certain factors on innovation. The first study examined the influence of corruption on innovation using the large panel dataset of 176 countries over a period of 18 years (2000-2017). Innovation has been represented using four proxies and they are categorized into: 1) innovation inputs (R&D expenditures and several researchers working in R&D sectors), and 2) innovation outputs (residential patents and the number of published journals and articles). Furthermore, a fixed effects model has been used for innovation inputs, while for innovation outputs, we used random effects. However, the empirical evidence has revealed a significant adverse impact of corruption on innovation activities represented in innovation inputs, yet, corruption has no impact on innovation outputs. Nevertheless, home corruption cannot be isolated from neighbouring corruption as many studies have attested to the fact that corruption is contagious. This has motivated us to extend our previous study and investigate the stimulus of contagious corruption on home innovation. This issue has been addressed in the second study using a dataset of 140 countries over a period of 15 years (2003-2017) with the Two Stages Least Squares model. In addition, the impact of neighbouring innovation or innovation spillover on home corruption has been considered using the random effects model. Our empirical findings disclose the fact that contagious corruption can definitely disturb home innovation and consequently can harm economic growth. Interestingly, our outcomes have demonstrated that the innovation of neighbouring countries could help the home country to be less corrupt (i.e. cleaner). From a different perspective, innovation can be represented as research productivity in terms of the number of documents and number of citations. In line with this, the third study has presented the effects of corruption, openness and the English language on research productivity and consequently, innovation. To address this issue, we have used mixed models, the hierarchal linear model and the data of 170 countries over the period of 1996-2018. Our results made it apparent that corruption and trade openness have a negative impact on research productivity. This means that countries which are less open to trade, because they tend to invest in the home country for research & development, have a higher rate of research productivity. English is a crucial factor in propagating documents through the citation process both because of being a global language and also because the top ranking journals are in English.

In accordance with the empirical evidence, we suggest the following policy implications in order to diminish corruption and help the country innovate more, allowing potentially the global innovation to flourish.

1. Governments/policymakers must focus on anti-corruption campaigns which have shown their effectiveness in reducing corruption.

2. Governments shall consider putting some policies in order to trigger innovation activities such as eliminating unnecessary bureaucratic and red tape barriers.

3. The policymakers are urged to undertake serious measures to spur innovative activities by eliminating the unnecessary bureaucratic matters that are the main cause of corruption and that lead to hindering economic growth and innovation.

4. Governments should encourage more innovation-friendly procedures by enforcing e-government services mainly designed to reduce the time of governmental procedures, eliminate unnecessary intermediaries and induce a fair access to information and services.

5. Governmental policymakers should set rules and regulations at the borders precisely because it is easier for corruption to travel as showed in Chapter 5. Fighting corruption locally and thus reduce home corruption can spill-over into neighbouring countries and help those to be cleaner and thus considered to be positive externalities.

6. Researchers or institutions could translate locally published documents into English so that local pieces of work can be globally exposed.

7. Governments should stress the importance of the research sector in economic and social development by establishing international universities, supporting international collaboration and increasing grants dedicated to research thus increasing R&D funds.

8. Governments must highlight policies which can help boost the research culture in countries.

In general, despite the sources of corruption, a nation's ability to innovate can be harmed through the misallocation of resources and this might consequently affect innovation outputs —documents & citations—and eventually deter economic growth. Therefore, in order to enhance national innovation levels, governments shall focus on setting rules and regulations to control corruption in addition to setting English as an official academic language.