"Knowledge spillovers as a base for economic upgrading in Global Production Networks (GPNs)": A case study for innovative Colombian manufacturing firms

Abstract

Globalization caused economies to become interconnected at a global scale in the end of the 20th century. More recently, economies have become knowledge-based as knowledge encourages innovation which may lead to increased economic performance of firms. In 2001, scientists came up with the organizational term *Global Production Networks (GPNs)* to position firms and locations within this internationalized knowledge-based economy. Since economies are subject to change through innovation, so are their positionings in GPNs. The purpose of the paper is to combine sources of knowledge spillovers and firm performance with theory on economic upgrading in GPNs. The focus is specifically on firms that do or do not participate in GPNs. The study is based on an empirical dataset for innovative manufacturing firms in Colombia, a country that showed tremendous economic growth over the past decades. The article concludes that national knowledge sources contribute to improved firm performance, while firms who are embedded in GPNs benefit more from innovation compared to firms that are not embedded in GPNs. Besides, we provide a detailed overview of the characteristics of firms that acquire relatively more sources of knowledge spillovers, while we link these spillovers to multiple types of improved firm performances as a result of innovation.

Keywords: Global Production Networks, knowledge spillovers, firm performance, manufacturing firms, Colombia

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Introduction

Today's interconnected economy, which is more often called a *'global economy'*, could be explained trough a historical process that started centuries ago. Some scientists call in the year 1492, when Christopher Columbus first stepped foot on the American continent (Tracy, 1990). O'Rourke & Williamson (2002) argue that this process of *'Globalization'* started during the second industrial revolution in the end of the 19th century. History shows that international trade and international economies have existed for a long time. Though, the 'real explosion' of international trade, that eventually made whole economies cross borders, followed later in the 20th century.

Thanks to improved international communication and infrastructure of all types, local companies have increasingly moved their operations internationally after the Second World War. As a consequence, national enterprises became *Multinational Enterprises (MNEs).* Originally, manufacturing companies in particular decided to move sections of their *Value Chains (VCs)* internationally, among others to seek for cheap labour (e.g. Dunning, 1981). Eventually, VCs were divided over multiple countries in the world which converted traditional VCs into *Global Value Chains (GVCs).* GVCs define the contribution of a place within the process of creation of a finished product or service (Dean, Fung & Wang, 2007). In order to describe and rank the positions of countries within those GVCs, scientists decided that those should be covered by a new organizational term. As a result, scientists came up with new terminology called *Global Production Networks (GPNs)* (e.g. Ernst & Kim, 2002, Neilson, Pritchard & Yeung, 2014).

While the globalized knowledge-based economy resulted in new terminology (GPNs) to describe and explain value chain processes, it has become clear that economies not only develop over time, but may also manage to catch up or even outpace traditional economic powers. These processes have led to a global shift of the economic center in the world (Dicken, 1998) and upward transition effects for firms within GPNs (Milberg & Winkler, 2011). Countries that were formerly recognizable for their low labour costs started to use the flows of incoming investments (also called *Foreign Direct Investment (FDI))* and knowledge to upgrade their positions within GPNs on an economic and social base (Barrientos & Gereffi & Rossi, 2011).

Most case studies on improvement within GPNs focused on Asia, for example on Taiwan (Chen, 2002) and Singapore (Van Grunsven, 2013). However, other parts of the world and particularly Latin American countries remain relatively less researched. Meanwhile, some Latin American countries show strong economic developments over the past decades, which resulted in huge increases of inward FDI in this region (Forte & Santos, 2015). One of these countries that shows high economic growth is Colombia. Historically, the country could be considered as a developing country as its economic sectors were mainly agricultural (DANE, 2019). However, its GDP per capita is almost 10 times higher in 2019 compared to 1990 (Worldbank, 2019a). Besides, data on inward FDI exposed a growth from 2.5 billion US$ in 2000 to over 16 billion US$ in 2014 (Worldbank, 2019b).

Earlier it was stated that next to FDI, incoming flows of knowledge helped firms, industries and whole countries to improve their positions within GPNs. Scientists have produced various studies in which they claim the importance of these *knowledge spillovers* (e.g. Grossman & Helpmann, 1991). As knowledge spillovers occur through different sources such as labour mobility spillovers (McCann & Simonen, 2005), meetings and conferences (Verspagen, 1997) or internationally through expatriates (Choi & Johanson, 2012), these flows have become difficult to catch as a total. Though, scientists were able to find relations between knowledge spillovers and innovation (e.g. Wang & Wang, 2012; Aghion & Jaravel, 2015). Besides, innovation may lead to improved firm performance (e.g. Wang & Wang 2012; Darroch, 2005). While knowledge spillovers include numerous sources, these appear to occur on different geographical scales (Simmie, 2003). Also, it remains unclear what the characteristics of firms are that relatively acquire more sources of knowledge spillovers.

One purpose of this study is to provide an overview of the characteristics of firms who obtain more sources of knowledge spillovers compared to other firms. Also, the focus is to link those sources of knowledge spillovers to performance improvements. Besides, as claimed Barrientos et. al. (2018), a higher economic performance can be related to upward economic transition in GPNs. Therefore, we make a comparison for firms that either do or do not participate in GPNs. To execute this study, we focus on a case study for Colombian manufacturing firms in 2018. As a result, the research question and sub question are as follows:

"To what extent do sources of knowledge spillovers relate to improved firm performance for innovating Colombian manufacturing firms that either do or do not participate in GPNs?"

Since knowledge spillovers exist on different geographical scales (Simmie, 2003) and it remains unclear what the characteristics are for firms who obtain more types of spillovers than other firms, we add the following sub question to our research:

- *What are the characteristics of firms that acquire more nationally and internationally originated sources of knowledge spillovers?*

Scientific, geographical & societal relevance

Existing literature on GPNs, knowledge spillovers and firm performance provided insight in a literature gap that generates scientific relevance for our study. Knowledge spillovers have earlier been combined with studies about GPNs (e.g. Ernst & Kim, 2002; Plank & Staritz, 2013) or have been directly coupled to firm performance (e.g. Audretsch & Lehmann, 2005; Wang & Wang, 2012). While existing literature would expect relations between the three concepts, so far we argue that it is not clear if and how these are connected. Besides, existing literature states that knowledge spillovers are difficult to catch as a whole and may be measured through various sources at different geographical scales. In our study we measure knowledge spillovers based on multiple sources that include both tacit and codified knowledge spillovers. Besides, these different sources are specified for the national and international scale level. Therefore, we argue that our study provides academic relevance as knowledge spillovers are defined in a more detailed manner that includes multiple geographical scales and compares those.

Also, this research focuses on innovating Colombian manufacturing firms. Earlier, the introduction discussed that existing research on GPNs mainly featured Asian case studies and that Latin American case studies in particular remain less researched. Colombia is rapidly growing, which is proven by its GDP per capita and inward FDI development in the past decades (e.g. Worldbank, 2019ab). As a result, we argue our geographical relevance by studying a relatively less researched, rapidly upcoming economy. Additionally, as we provide an overview how theoretical concepts are related to each other, local policy makers in rapidly developing economies may get to know how they should encourage manufacturing industries in a desired direction. A main goal of our study is to provide detailed information how firms attract certain sources of knowledge spillovers and how these are expected to impact their performances through innovation. Besides, manufacturing firms themselves may get to know the benefits of innovation and the importance of various types of knowledge spillovers or participation in GPNs. The results of this study might provide information for these firms to strategically improve their economic positions in their GPNs. Based on these statements, we argue the societal relevance of this study.

The article is structured into different sections that together provide an answer to the main question of this thesis. *Chapter 1* focuses on existing theories about GPNs, knowledge spillovers and firm performance. Later, *Chapter 2* focuses on the methodology that is used for the analyses of main- and sub questions, while *Chapter 3* provides a background on our case study. Then, *Chapter* 4 presents the results that are found through the analyses, to finally end with a *Conclusion & Discussion.*

1. Theory

The *Introduction* came up with various terminologies that together form the 'heart' of this study. This chapter provides a theoretical background that explains this terminology. This chapter is structured into four paragraphs. *Paragraph 1.1* discusses the evolvement from VCs to GPNs, while *Paragraph 1.2* discusses the positioning & upgrading in GPNs. Then, *Paragraph 1.3* explains more about knowledge spillovers, while *Paragraph 1.4* links these spillovers with firm performance and GPNs.

1.1 From Value Chains (VCs) to GPNs

While Moore & Lewis (1998) argue that Multinational Enterprises (MNEs) already existed for a long time, operations were increasingly moved across borders after the Second World War. MNEs traditionally have multiple reasons to cross borders. Primarily, factors such as lower labour costs (Dunning, 1981) were the main drivers for manufacturing companies to cross borders. Dunning (1977) came up with a structure that explains why companies have become MNEs: the OLI-paradigm. Firstly, companies may have *Ownership* advantages when becoming MNEs, which may include an extended skill acquisition. Secondly, reasons can be based on *Locational* or geographical advantages, such as the availability of natural resources. Thirdly, becoming international may be a result of advantages regarding the *Internalization* of a process instead of outsourcing it to a local producer (e.g. Crescenzi, Pietrobelli & Rabellotti, 2014).

As firms moved their operations, economies started to cross borders on a larger scale than ever. Since the 90s of the former century, this process is called the globalization of economies (e.g. Dicken, 1998). When MNEs started to move operations internationally, this process influenced their Value Chains (VCs). In a traditional situation, companies would first extract or import raw materials, before executing the manufacturing processes that converted these materials into products. In the end of the VC, these products were then distributed and sold. All vertical stages from raw materials up to the stage in which a product is sold, are part of a product's VC (Kogut, 1985). All, or at least most of these sections of the 'chain' would traditionally be located within the same country. However, since companies increasingly started moving the 'stages' in their VCs for OLI-related reasons, VCs crossed borders. Besides, MNEs found that specific countries or regions had competitive advantages in various 'segments' of the VC and MNEs started to act on that. As a result, production processes have become thinner and thinner and even became distributed intercontinentally. Thanks to the large scale on which this process occurred for MNEs, original VCs have become 'Global Value Chains (GVCs) since (Dean et. al., 2007).

Among scientists, many have tried to come up with explanations of stages or steps within GVCs. However, it must be clarified that GVCs vary per industry and sector. In order to structure existing types of GVCs, Gereffi, Humphrey & Sturgeon (2005) divided all GVCs in five different governance types. While this division provides some theoretical insight into the elements of GVCs, others focused on a more specified structure for GVC's elements. A different structure, which was discussed in Fernandez-Stark, Bamber & Gereffi (2011) forms a 'basic structure' for GVCs that was in this case applied on the global fruit industry. As we derive from *Figure 1,* Duke GVCC separate the global fruit industry into five components. Scientists used this simplified version to explain GVCs from a product-based perspective.

Figure 1: General sections in the GVC in the fruit industry

Source: Duke GVCC, (no date). Discussed in (Fernandez-Stark et. al., 2011)

In GVCs, each section from the lower stages up to the higher stages adds higher value to the product. In general, the higher a stage is in the GVC, the higher is its added value to the product. Therefore, countries and places want to attract higher segments in the GVCs of MNEs (Henderson, Dicken, Hess, Coe, & Yeung, 2002). Functions such as *inputs, production for export* and *distribution & marketing* might be involved in any manufactured good. Though, GVCs may differ completely for larger MNEs or more complex industries. As a result, Sturgeon (2008) came up with a general and more precise structure that takes scale and complexity into account and would also be applicable on service-related MNEs. Their structure is added in *Table 1:*

Table 1: Distribution of VC sections

Core VC Stages	Support VC Stages
Headquarters	Business services
Research & Development	Human resource management
Manufacturing	Technical services
Logistic and distribution	Firm infrastructure
	Customer and after-sale-services

Source: (Sturgeon, 2008) Discussed in (Crescenzi et. al., 2014). Edited by author

In this structure, *VC* functions are not necessarily ranked, but divided into *Core* and *Support* related VC stages. While *Core and Support* related functions can be combined at one location, each segment has location specific requirements. For example, a R&D location meets different necessities compared to a manufacturing plant (Crescenzi et. al., 2014). GVCs may to some extent provide insight in the distribution of VC functions between countries and places. However, the system may be considered a bit vague when determining positions of countries within an integrated world economy. Not only do GVCs differ for each type of industry (Gereffi et. al., 2005), also it is not clear how sections of GVCs determine a position within the global economy. As it was already described by Ricardo (e.g. described in (Ruffin, 2002)), each place should focus on its competitive advantage to benefit most in an economic system. Therefore, a new structure was needed to organize these ongoing processes for MNEs and their locations.

Consequently, scientists came up with new terminology that would help to position firms, regions or countries combining their contribution within various GVCs with their positioning in the global network. As a result, scientists announced the organizational concept called Global Production Networks (GPNs). While GPNs were first mentioned in the beginning of the 90s of the 20th century (Storper, 1991), the concept was more widely discussed in groundbreaking academic papers by Ernst & Kim (2002) and Henderson et. al., (2002). GPNs particularly feature a new organizational context, as they comprise existing definitions in evolutionary economic geography. GPNs include flows of capital (FDI) and knowledge between spaces in an international, national and regional context. Then, they position firms or locations based on their positions in GVCs and their value-added activities (Ernst & Kim, 2002). More recently the concept was described by Yeung & Coe (2015):

"Global production networks (GPNs) are organizational platforms through which actors in different regional and national economies compete and cooperate for a greater share of value creation, transformation and capture through geographical dispersed economic activity" (Yeung & Coe, 2015).

This definition of GPNs specifically mentioned competition, but also cooperation at a regional and national context. Therefore, Yeung & Coe (2015) indicate that firms who participate in an international environment, strategically couple the flows they obtain in a

regional or national environments. Theoretically, this would mean that firms or locations that are connected in these GPNs would be more successful as these would be able to couple these flows more strategically than firms that are not connected in GPNs. Firms that are connected in GPNs perform better while coupling these flows and can therefore generate more value creation (Yeung & Coe, 2015).

1.2 Positioning & upgrading of GPN

When MNEs increasingly crossed borders, they brought two crucial elements to developing countries: FDI and knowledge flows. Former developing countries used both flows to organize their own industries and later established their own MNEs. This development changed their position in the world economy and eventually led to a global shift of the economic center, particularly towards Asia. This effect confirms an earlier study by Dicken (1998) which stated that one of the key characteristics of global economies is that these are changing all the time.

Economic developments in Asia also affected the positioning of their industries within GVCs. Besides, these developments resulted in a domino-effect as they created more aggregated value, inward FDI and knowledge flows. Therefore, GPNs are affected and positions are changeable. For example, there is the position of Singapore: a former colonial trade post, that developed itself into a 'gateway city' in the 20th century and has become one of the richest places in the world in the 21st century (Van Grunsven, 2013). Singapore as a country, but also its firms strongly improved their positions within GPNs. These developments did not only occur in Singapore, but in fact occurred in many other places such as China (Barrientos, Gereffi & Rossi, 2018), Taiwan (Chen, 2002), but also in Panama more recently (Sigler, 2014).

But what defines upgrading within GPNs? Some scientists argue that the improved position within GPNs, thus through positive performance, positively affects the economy on the regional level (e.g. Yang, 2013, Yeung & Coe, 2015). As a result, Milberg & Winkler (2011) came up with a well-cited study that links improvements in export statistics to economic and social upgrading on the local, regional and national level. On the one hand economic upgrading was directly linked to 'industrial upgrading', being scale and efficiency upgrading for manufacturing companies. On the other hand, social upgrading was mainly focused on workers, including their wages and labour rights (Milberg & Winkler, 2011).

At the same time Barrientos et. al. (2011) studied the same linkage between GPNs and upgrading on both the economic and social level. This model was considered suitable for case studies in labour intensive industries such as a case study for the Moroccan garment industry (Rossi, 2011). Existing research specifically focused on the sectoral level. As a result, Barrientos et. al. (2018) came up with a new insight on economic and social upgrading in GPNs based on the firm level, which described economic upgrading of firms within GPNs based on improved economic performance of a firm.

1.3 Defining knowledge spillovers

The introduction and former paragraphs already announced the term 'knowledge flows' and their importance for the development of firms and economies. Economies have become knowledge-based economies since the end of the 20th century. Among others, knowledge-based economies evolved as a result of the 'internet revolution', which resulted in a growing importance of innovation (Harari, 2016, p16). Since the economy had become a global economy, focusing on knowledge and innovation became key interests on a global level. Asian economies especially managed to catch up with the former global leaders, as was discussed earlier in the former paragraphs. But, how did they?

MNEs provide streams of FDI and knowledge by acquiring local firms either 'at arm's length' or by establishing their own locations abroad. In general, local firms and countries may benefit from inward FDI, as shows China (Liu, Wang & Wei, 2009). Besides inward FDI, these locally established MNEs started using the external knowledge and invested in their own R&D facilities. The extraditions of knowledge within firms are called 'knowledge flows' (Gupta & Govindarajan, 2000). However, through interchanges between firms or individuals the knowledge 'spills over' from one to another. Therefore, many literature sources call these flows 'knowledge spillovers'. Since this study focuses on intra-firm or other types of external knowledge spillovers, we used this terminology in our study.

Knowledge exists in various forms. Economic geographical theory divides knowledge into *1) Codified knowledge* and *2) Tacit knowledge.* Codified knowledge is any kind of knowledge that can be described through words, images or video material. Knowledge can be spread through various methods, for example through books or academic articles. Consequently, knowledge 'spills over' since people learn about the knowledge while reading it (e.g. Polanyi, 1961). Next to codified knowledge, tacit knowledge is different and harder to obtain. Tacit knowledge can be considered as non-traceable forms of knowledge that cannot be codified. Tacit knowledge is acquired through informal learning of behavior and working procedures that may to some extent be learned without someone's awareness (Howells, 2002).

Former parts discussed that knowledge flows or 'spills over' particularly within MNEs that relocated VC sections across borders. However, various scholars detected intra-firm knowledge spillovers occurring at multiple scales. Among others there are Glaeser, Kallal, Scheinkman and Shleifer (1992) who claim that especially for newly created knowledge, knowledge transfers occur more locally than internationally. Though, on the international level, Kotabe, Dunlap-Hinkler, Parente & Mishra (2007) claim the importance of cross-national knowledge. However, both studies did not provide deeper insight in the sources of knowledge spillovers. Some argue that knowledge spillovers are not detectable (e.g. Kaiser, 2002). However, others suggest that MNEs encourage cross-national knowledge dispersion through external processes. A famous study by Smarzynska Javorcik (2004) argues that knowledge may spread from foreign MNEs to domestic firms through backward linkages, that provide knowledge spillovers to local firms. Others claim that the dispersion of knowledge occurs through expatriates (Choi & Johanson, 2012) or through labour mobility (Foster-McGregor, & Pöschl, 2016). Besides, other scientists describe that knowledge spills over in specific situations and suggest the importance of conferences (Verspagen, 1997) or face-to-face meetings (von Hipple, 1994). Overall, there exist many situations that may provoke extraditions of tacit knowledge. Additionally, extraditions of codified knowledge make knowledge spill over indirectly. As a result, we argue that scientists provided numerous insights how and why knowledge spills over. Though, some firms may acquire more of these sources of knowledge spillovers than others. Therefore, Kaiser (2002) suggests that firm characteristics may influence the knowledge spillovers that firms obtain.

Various academic studies related the education level of employees to knowledge spillovers that were obtained in a firm. Foster-McGregor & Pöschl (2016) claim that there exists a positive relation between labour mobility of high educated workers and internationally originated knowledge spillovers, which was observed for high-tech manufacturing firms in Europe. Besides, Markusen & Trofimenko (2009) found similar results which claim that higher educated workers acquire more foreign skills by international experts compared to their lower educated colleagues. Though, both types of workers may obtain knowledge spillovers. In scientific literature, workers including their knowledge are often combined as 'Human capital'. As a result, we provide our first hypothesis;

- *Hypothesis 1: Human capital relates to more acquired sources of national & international knowledge spillovers*

Besides education and the number of workers, various sources claim the impact of geographical location on knowledge spillovers. Among others, there is the well-cited article by Audretsch & Feldman (2004) that significantly proves the relation between

knowledge spillovers and geography. This theory has later been applied to various sectors and for various types of geographical scales. On the one hand, lots of studies mention the relation between geography and knowledge spillovers on a very local level through geographical proximity. These claims would suggest the importance of geography for incoming knowledge spillovers on the national level. One the other hand, firms need external knowledge to reduce the chance of a cognitive lock-in (Boschma, 2005). Besides, e.g. Ang & Madsen (2015) prove the significant impact of geography on obtaining international knowledge spillovers. They claim that firms that are located near physical borders generate more cross-national knowledge spillovers. While Ang & Madsen (2015) focused on physical borders, Conventz & Thierstein (2011) discussed knowledge spillovers caused by Schiphol Airport in the Netherlands. Therefore, the proximity to international air- and seaports might impact the obtained sources of international knowledge spillovers. Based on these literature sources, we expect a relation between the geographical location of firms and the different types of knowledge spillovers that are acquired by firms. As a result, our second hypothesis is:

- *Hypothesis 2: Geographical location impacts the firm's obtained sources of national & international knowledge spillovers*

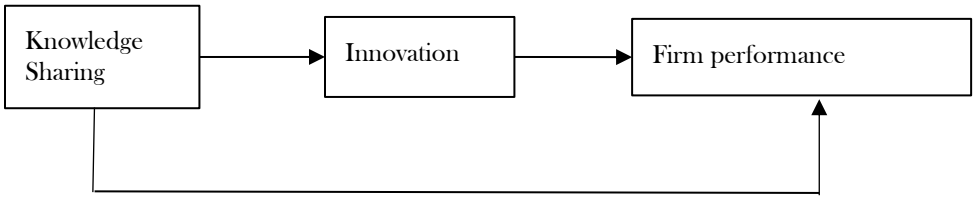
Then, in the former paragraph about upgrading in GPNs, it was discussed that firms who operate in GPNs are able use regional, national and international knowledge sources more strategically. This process of strategic coupling could eventually lead to positive economic effects in a region (Coe, Hess, Yeung, Dicken & Henderson, 2004) or on the firm level (Barrientos et. al., 2011). As a result, it would be expected that those firms that operate in GPNs, acquire more sources of national and international knowledge spillovers than firms who do not participate in GPNs. As a result, we propose our third hypothesis:

- *Hypothesis 3: Firm embeddedness in GPNs positively relates to more acquired sources of national & international knowledge spillovers*

1.4 Linking knowledge spillovers, GPNs and firm performance

If knowledge eventually spills over, it provides resources that could be used for innovation. For example, a case study for the American pharmaceutical industry found a relation between knowledge spillovers and innovation. It states that cross-national knowledge spillovers encourage innovation. However, according to the authors it should be noted that international knowledge spillovers should be limited to no more than 45% of its knowledge resources for innovation (Kotabe et. al., 2007). Then, national knowledge spillovers are also suggested to be of major importance, which was proven by various scientists (e.g. Audretsch & Feldman, 2004). If innovation eventually turns out to be successful, it may impact the firm's performance. Yet, various scientists have studied the relations between these terminologies. Among others, there are Wang & Wang (2012) who combined the concepts into a framework, which is presented below:

Framework 1: Existing research model on knowledge, innovation & performance



Source: (Wang & Wang, 2012)

The model assumes a direct and indirect relationship between what Wang & Wang (2012) call 'knowledge sharing' and firm performance. Knowledge sharing in this case explicitly focused on inter-firm knowledge sharing. However, evidence is also found for intra-firm knowledge spillovers (Gilbert, McDougall & Audretsch, 2008) or for other types of spillovers such as labour mobility (e.g. McCann & Simonen, 2005). In *Framework 1*, firm performance was measured through various elements including an improved productivity of

operations and cost reductions (Wang & Wang, 2012). Besides improved productivity of operations and costs reductions, firms may enjoy other performance improvements that are a result of innovations. For example, more recently, innovations occur with a stricter focus for sustainability (Sezen & Cankaya, 2013).

While various authors claim a relation between intra-firm knowledge spillovers and firm performance (e.g. Gilbert et. al., 2008; Belderbos, Carree, Lokshin, 2014) some scientists claim that firms not necessarily benefit from external knowledge. Explicitly knowledge spillovers that are obtained 'too locally', potentially result in a cognitive lock-in as we mentioned earlier (Boschma, 2005). Therefore, we expect that it is important for firms to obtain knowledge spillovers from multiple sources at different geographical scales, which is also suggested by Belderbos et al. (2014). As a result, the fourth hypothesis of our research is:

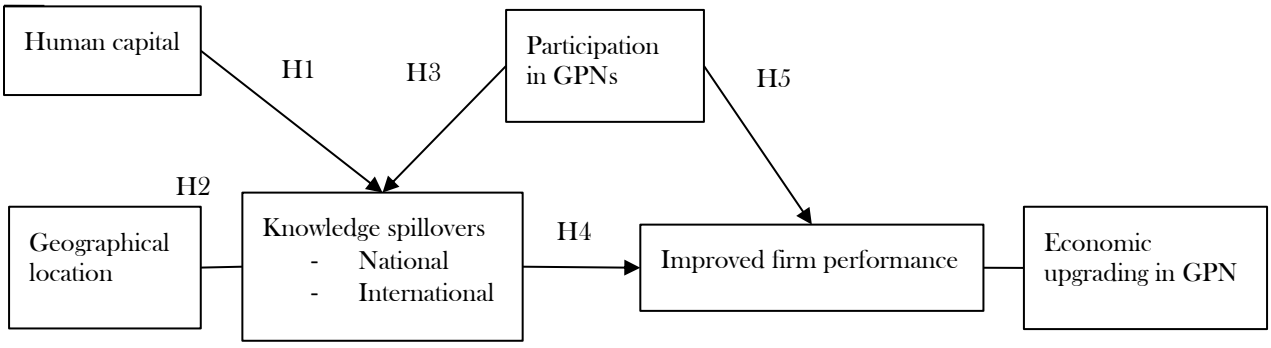
- *Hypothesis 4: A higher number of sources for national & international knowledge spillovers relates to improved firm performance*

Earlier in *Paragraph 1.3* we argued that firms that participate in GPNs strategically use geographical scales. As a result, we suggested a relation between GPNs and sources of knowledge spillovers. For relations between GPNs or other types of networks and firm performance, existing research presents various situations in which relations exist between the concepts. In general, firms that act in an international environment may benefit from economies of scale, which could result in higher economic performance of that firm. Also, there have been numerous empirical studies that claim a relation between participation in international networks and firm performance. For example, when we look for literature on network embeddedness, there are Dacin, Ventresca and Beal (1999) who argue, based on an empirical study, that firms who are to a higher extent embedded into international networks generate improved firm performance. Moreover, Kraemer, Gibbs & Dedrick (2005) claim that firm participation in GPNs, through e-commerce use, had positive effects on firm performance. As we research for a direct effect in our study, the fifth hypothesis is:

- *Hypothesis 5: Firm participation in GPNs positively relates to improved firm performance*

The theoretical section has provided a detailed background on the topics that together form the essence of this research. Besides, it structured existing literature in a way that it creates possibilities to study our case study of innovating Colombian manufacturing firms. In order to provide a better visualization of the elements that are researched, we provided a conceptual model for researching the hypothesis. This model, which is presented in *Framework 2,* provides an overview of the five hypothesis that were proposed during our theoretical study. The hypotheses are recognizable by H1-5. The arrows and connections in the model represent the expected relations. Besides, the connection between improved firm performance and economic upgrading in GPN is not researched but suggested by existing literature by Barrientos et. al. (2018).

Framework 2: Conceptual model for research



Source: Various sources. Edited by author

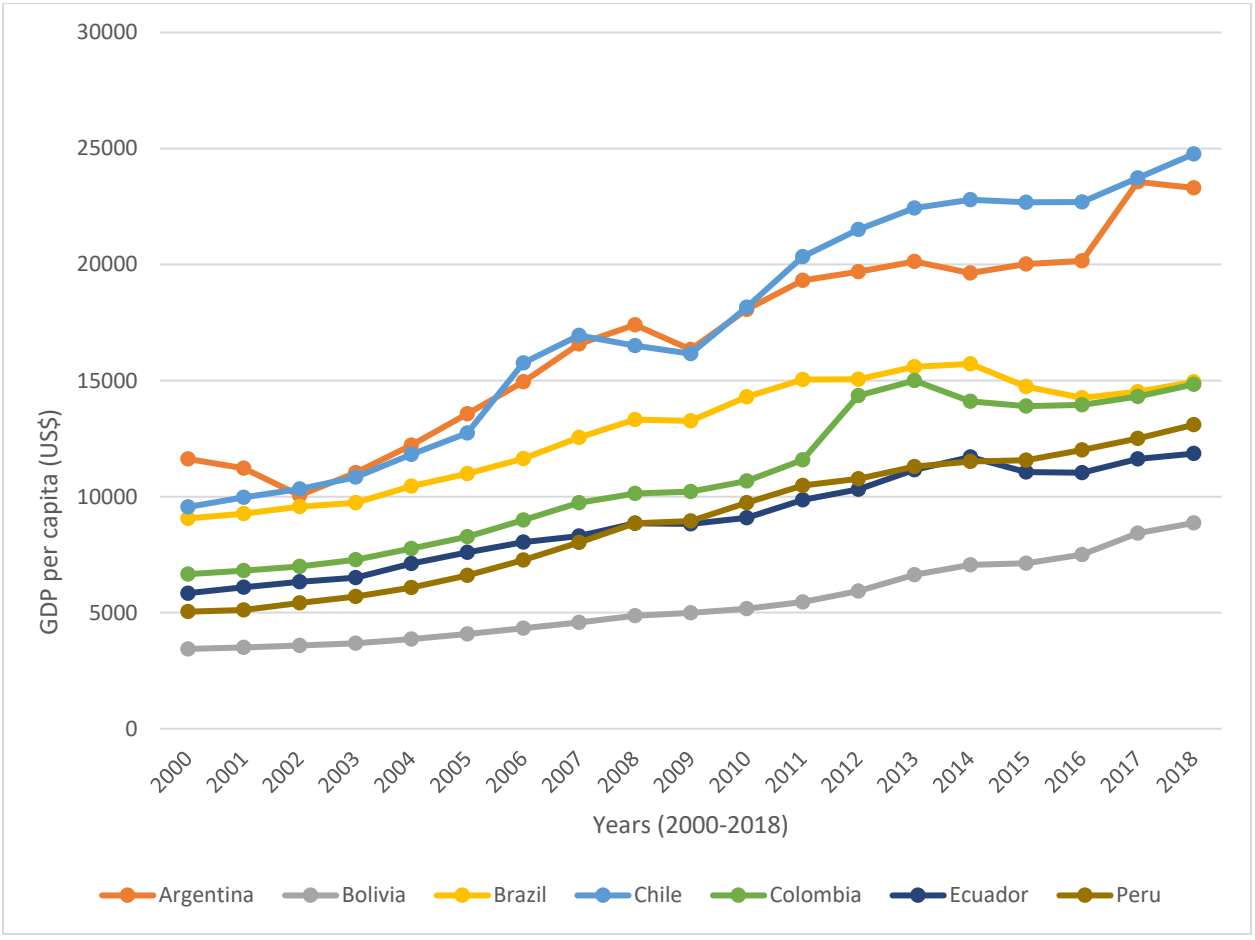
2. Case study description

In the *Introduction* it was mentioned that this study focuses on a case studie for Colombian manufacturing firms. In order to understand Colombia's current manufacturing industry, this case study description provides a background on Colombia's economy.

Colombia had to deal with various problems of political instability in the end of the 20th century when economies became global economies. Especially from the 80s onwards, various political groups (among others FARC and ELN) participated in a guerilla warfare that destabilized the country politically, but also economically. Besides guerilla warfare, Colombia experienced other major problems with the narco-trafficking cartels. Due to this political instability and the lack of safety, its economy suffered tremendously (Worldbank, 2020). Therefore, to a large extent, Colombia did not enjoy the possibilities that countries in Asia had.

However, the Colombian government signed a historic treaty with FARC in 2016 (Colombian National Government, 2016). Now, Colombia is at peace for almost all of its nearly 50 million inhabitants in 2018 (Worldbank, 2020). While the country suffered from an intense economic crisis in 1998, Colombia's economy particularly started to develop rapidly from the beginning of the 21st century onwards. The countries' GDP per capita was only 1500$ in 1990 but increased to 14000$ in 2018. The development of Colombia's GDP per capita compared to other countries in the region are visualized in *Figure 2* (Worldbank, 2019a).

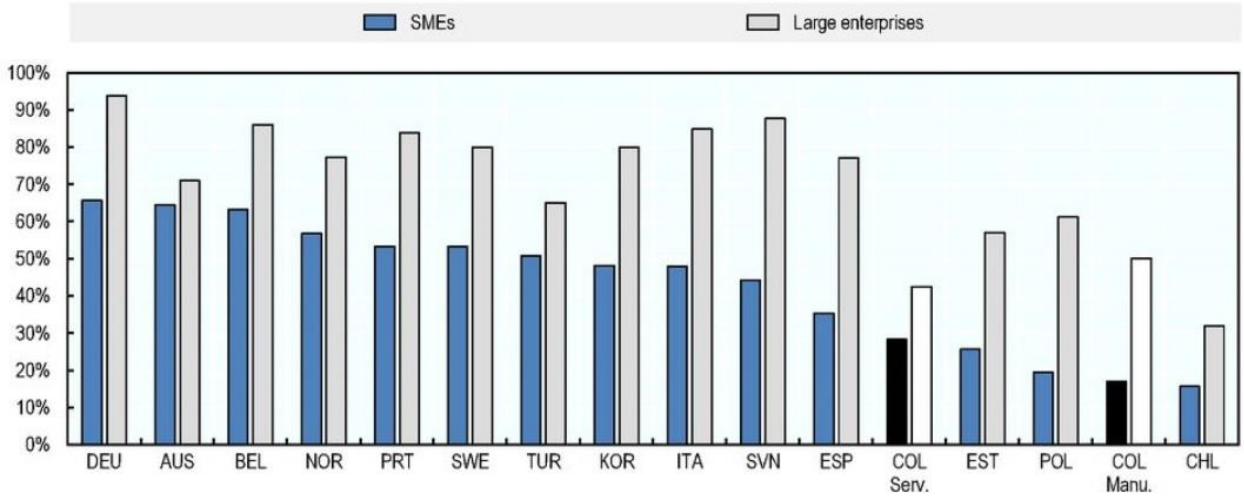
Figure 2: GDP per capita for Latin American countries 2000-2018



Source: (Worldbank, 2019a). Edited by author

As the information in *Figure 2* shows, Colombia is following a similar developing track compared to other Latin-American countries. Its GDP per capital grew to an equal amount to Brazil's GDP per capita in 2018. Though, countries such as Chile and Argentina remain in higher positions. When Colombia started growing rapidly in the beginning of the 21st century, it was to a large extent thanks to its manufacturing industry. Colombia's manufacturing industry contributed to about thirteen percent of the national GDP in 2017 (Worldbank, 2019b). However, in recent years from 2015 until 2019, the aggregated value by the heavier manufacturing industry declined and Colombia showed a larger focus on other sectors. Sectors that grew in importance included less complex agricultural sectors, while we also found a stronger focus on the financial service sector (OECD, 2019). While dependence on heavier manufacturing industries declined, so did the country's growth. As a result, the OECD advised Colombia to continue focusing on its manufacturing sector to regenerate stronger economic growth rates (OECD, 2019). Besides, OECD economists encouraged Colombian manufacturing firms to focus more on innovation. As we compare innovation for Colombian firms to other countries' statistics, we find that only 20% of the Colombian manufacturers innovated in 2016 (DANE, 2017). The comparison for innovativeness for Colombia and other OECD countries' firms is visualized in *Figure 3.*

Figure 3: Percentages of innovative firms for OECD countries



Source: (OECD, 2019)

When Colombia's manufacturing and service sector is compared to other countries, we note that Colombian firms are relatively less innovative compared to western countries such as Belgium or Sweden. Though, compared to Chile, Colombia's firms are more innovative (OECD, 2019), which creates an interesting perspective in current knowledge and innovation-based economy.

Since this study focuses on embeddedness in GPNs, import and export statistics may provide a general insight for Colombia. According to OEC (2017) data, Colombia has a negative trade balance. Colombia is the world's 55th exporter, while being located 53rd on the Economic Complexity Index (ECI). On the one hand, its main exportations include crude & refined petroleum, coal briquettes and coffee. More complex manufactured products are not strongly present, but upcoming. On the other hand, Colombia's main imports include computers, broadcast equipment, medical equipment and cars.

On a regional level, Colombia is divided into 32 departments. Since the country is vast in size, its manufacturing industries are to a large extent located in the countries' main cities: Bogota, Medellin and Cali, but also along the Atlantic coastline (Balat, Casas & Casas, 2018). Besides, on the regional level there exist large differences in international trade. In a report on production and transformation

policy, the OECD stated that the departments of Bogota D.C, Antioquia and Cundinamarca in total aggregated 60% of Colombia's total FDI stock in 2017 (OECD, 2019). Besides, when we look at import and export data for Colombian departments, we find that these three departments are by far the largest exporters and importers (DANE, 2019).

3. Methodology & data description

The theoretical section provided five different hypotheses for research that were substantiated based on existing literature. Our hypotheses provided suggestions for relations between the three main concepts of our study; GPNs, knowledge spillovers and firm performance. This chapter is organized into three different parts. First, we discuss the methods that were used for analysis. Then, we operationalize the models that were used, including equations and variables. Later, we describe our data including descriptive and collinearity statistics.

3.1 Methods of analyses

The purpose of this thesis was to find relations between our three key concepts and apply those on a sample of Colombian manufacturing firms. As our goal was to generalize the results for all Colombian manufacturing firms, we considered quantitative analyses more suitable to answer the proposed hypotheses. Additionally, quantitative analyses made us able to statistically prove the expected relations. Part of our hypotheses focused specifically on knowledge spillovers and the characteristics of firms that obtained those, while the second set of hypotheses focused on firm performance. As a result, we divided hypotheses 1-3 into one group and hypotheses 4-5 into a second group. Our first three hypotheses researched characteristics of firms that obtained different kinds of knowledge spillovers. Existing literature stated that knowledge spillovers, either codified or tacit, may occur in many forms and are difficult to catch as a total (Kotabe et. al., 2007). As a result, we detected different kinds of knowledge spillovers that could be considered as equal sources. Therefore, we argue that we research counts of sources for knowledge spillovers. Besides, existing theory mentioned that knowledge spills over at various scales (e.g. Glaeser et. al., 2002). Therefore, we included nationally and internationally obtained sources of knowledge spillovers in our study. Since we used two different levels for the same firm characteristics, we argue that we needed two similar models for statistical analyses.

Since we are measuring counts for equally weighted knowledge spillovers, we argue that Poisson regression models were most suitable for models 1-2. Since a total of 23 sources of knowledge spillovers were used in the analyses, it was expected that the distribution would be extremely skewed and not normally distributed. This would then lead to biased standard errors and significant scores as a result of heteroscedasticity (Coxe, West & Aiken, 2009). Therefore, the results would have been hard to explain and generalize for all firms in the dataset if we would have used standard OLS regression analyses. As a result, we considered Poisson regression most suitable for models 1-2 as our data is in line with criteria mentioned in existing literature on Poisson regression analysis. Also, we opted for measuring knowledge spillovers in 2018. As a result, we argue that our study for models 1-2 is cross-sectional.

Then, hypotheses 4-5 suggested possible links between the three main concepts, in which firm performance was used as a dependent variable. Existing literature provided us multiple insights in firm performance as a concept (e.g. Wang & Wang, 2012). Besides, in the theoretical section, we argued that firm performance could be linked to what Barrientos et. al. (2018) described as economic upgrading in GPNs. We decided to measure firm performance based on three dependent variables that can somehow be linked to economic upgrading: *1) Improved productivity, 2) Reduced communication costs and 3) Improved sustainability.* As a result, we argue that we needed three different models for hypotheses 4-5. All three models had similar independent variables, while the dependent variables were all categorical variables. Besides, the dependent variables were measured in categorizes that were ordinally ranked. *Improved productivity* and *reduced communication costs* were defined based on three ordinally categories, while *improved sustainability* was

measured based on five categories. Since we used a categorical variables as our dependent variable that were also strongly ordinally ranked, standard linear logistic regression would not be applicable. Therefore, we opted for three ordinal logistic regression models. Ordinal logistic regression analysis takes the ranking of categorical variables into account, while researching the effects of the independent variables as predictors of the outcomes for all individual cases in the dataset (Brant, 1990). Same as for models 1-2, we used data for 2018, which makes our study cross-sectional.

3.2 Operationalization

This section explains the operationalization of the research methods that were substantiated in the former paragraph. As it was discussed earlier, the hypotheses were divided into two groups. Therefore, this section is structured based on the division of the hypotheses.

3.2.1 Hypotheses 1-3

Earlier it was mentioned that models 1-2 used different geographical scales to measure knowledge spillovers. Though, independent variables were the same for both models. Based on the first three hypotheses, the predictors for models 1 and 2 included *human capital, geography* and *participation in GPNs* [1]. The equations that were used for models 1-2 were as follows:

- **Model 1:** $NatKnowSpil_i = \alpha EducIndex_i + \beta NumbWork_i + \gamma Bog_i + \delta Anti_i + \theta Cund_i + \varphi GPNindex_i + \varepsilon_i$ (1)

- **Model 2:** $IntKnowSpil_i = \alpha EducIndex_i + \beta NumbWork_i + \gamma Bog_i + \delta Anti_i + \theta Cund_i + \varphi GPNindex_i + \varepsilon_i$ (2)

in which i represented each individual firm, and ε features the part that was not covered by our model. The dependent variables *NatKnowSpil* and *IntKnowSpil* were computed based on 23 sources of knowledge spillovers that were equally weighted [2]. Besides, we decided to split human capital into two different variables in the analysis: *EducIndex* and *NumbWork*. While *NumbWork* represented the total number of workers for each manufacturing firm, the *EducIndex* was calculated based on the following equation:

$EducIndex_i = \frac{UniGrad_i}{NumbWork_i} \times 100$ (3) [3].

Additionally, the geographical component was added in the equation. *Bog, Anti and Cund* represented the Bogotá D.C, Antioquia and Cundinamarca departments of Colombia. In the case study description, it was stated that those three departments generated over 60% of all inward FDI in 2017 (OECD, 2019). Therefore, these were compared separately to Colombia's other 29 departments. In the original dataset, each department was recognizable by a number that represented the location, which we converted into department names (DANE, 2019). Since the dependent variable was on the firm level, while the geographical variable was on the plant level, this variable had to be converted to the firm level. The geographical variable was converted to the firm level based on the assumption that the plant with the highest number of workers is the firm's main location. Then, we made dummy variables for all three departments [4].

[1] The variables were conducted in IBM SPSS Statistics 26.
[2] Equations for both dependent variables are added in *Appendix 1.*
[3] UniGrad is calculated based on the total number of PhD, MsC, Bsc and Bsc of applied sciences graduates for each firm.
[4] While we found a geographical component for our research, we are aware that the department level is not specific enough to fully describe the relation between geographical location on our dependent variable. Therefore, this is considered a limitation of our study.

Additionally, *GPNIndex* was included in the equation. As we wanted to build an index score that calculated the degree in which firms are embedded in GPNs, import costs *(ForeignRec)* and export revenue *(ForeignRev)* were used to compare to the total resources costs *(TotalRec)* and revenues *(TotalRev)* for each firm. Again, we used data on the plant level that first had to be converted to the firm level. The variables were converted based on the following general equation: $X_i = \sum_n X_\alpha$ (4)

in which i represents each individual firm, n stands for the number of plants for each firm and α stands for each individual plant. Then, all necessary variables were combined to calculate our *GPNindex*. To do so, the following equation was used:

$$GPNIndex_i = \frac{\left[\frac{ForeignRec_i}{TotalRec_i}\right]+\left[\frac{ForeignRev_i}{TotalRev_i}\right]}{2} \times 100 \ (5)$$

in which i represents each individual firm. As a result, the equation provided index scores for each firm and ranked their embeddedness in GPNs.

3.2.2 Hypotheses 4-5

Models 3-5 covered the statistical testing for hypotheses 4-5. Three similar regressions with similar independent variables were used for this part of the analyses. The equations for models 3-5 were as follows:

- **Model 3**: $ImprProd_i = \alpha NatKnowSpil_i + \beta IntKnowSpil_i + \gamma PartGPN_i + \varepsilon_i$ (6)

- **Model 4**: $RedCom_i = \alpha NatKnowSpil_i + \beta IntKnowSpil_i + \gamma PartGPN_i + \varepsilon_i$ (7)

- **Model 5**: $ImprSust_i = \alpha NatKnowSpil_i + \beta IntKnowSpil_i + \gamma PartGPN_i + \varepsilon_i$ (8)

in which i represented each individual firm, and ε featured the part that was not covered by our model. Model 3 used the variable *ImprProd,* which stands for improved productivity as a dependent variable. This variable was already in the dataset and was based on a categorical variable in the survey. This variable was not adapted from the original dataset. However, we opted to turn the ranking the other way around, as it would help to analyze the results [5]. The same changes were applied for the variables that were used for reduced communication costs *(RedCom)*[6] and improved sustainability *(ImprSust).* While improved productivity and decreased communication costs were based upon one categorical variable in the original dataset, two categorical variables were used to describe improved sustainability. For calculating improved sustainability, the following equation was used to count both categorical variables:

$ImprSust_i = RedEner_i + RedRec_i$ (9)[7] in which i represented each individual firm. Then, the three models represented three independent variables. *NatKnowSpil* and *IntKnowSpil* were already explained in the former section and we did not change these variables as we considered these suitable for models 3-5. Besides, *PartGPN was* used as a dummy variable in which we selected the firms that both imported and exported. These firms were selected based on the variables *ForeignRec* and *ForeignRev* in the original dataset. *GPNIndex* was not used as we wanted to divide firms that either were or were not participating in GPNs to make a stronger distinction.

[5] The original ranking varied from 1=high improvement, 2=low improvement, 3=zero improvement. We converted the data into 0= no improvement, 1= low improvement, 2=high improvement.

[6] Same as for ImprProd, DecCom was already in the dataset.

[7] RedEner stands for reduced energy use, while RedRec stands for reduces use of resources.

3.3 Data description

On a yearly basis, the Colombian organization for statistics *DANE* holds various surveys among manufacturing industries based in all the countries' department. Among those surveys there exist data that describe general information about randomly selected manufacturing firms on the plant level: the *Encuesta Anual Manufacturera (EAM).* Another survey, the *Encuesta de Desarrollo e Innovación Tecnológica (EDIT)* researches innovation and provides information upon innovation and its effects on the firm level. Both datasets for 2018 are very detailed and originally include over 500 variables each. In total, both datasets respectively featured 7911 and 7529 randomly selected firms that pay tax to the Colombian government (DANE, 2019ab). As a result, the data featured a sample that was representative for the population, which are all manufacturing firms in Colombia in 2018.

Since both datasets included elements that were required to research the main question of this research, the original datasets had to be merged. Merging the datasets was possible as both datasets included the common variable *Nordemp,* which represented the identity number on the firm level. As the data for the *EAM* was originally on the plant level, some variables had to be converted to the firm level [8]. Then, variables were merged which resulted in 5988 successfully merged cases on the firm level, excluding the missing cases for variables in one of the two datasets. The *EDIT* dataset provided a detailed overview of the variables that were discussed in our operationalization. However, we detected an important shortcoming for the data. Since the *EDIT* dataset focusses specifically on innovating firms, those who did not innovate in 2018 were not asked for knowledge spillovers or improved firm performances. As a result, we had to filter only the firms that innovated in 2018, which created a bias in our research. Since the dataset provided a variable that researched the number of innovations, all firms that executed at least one innovation in 2018 were selected. As a result, 1249 of the original 5988 firms met the requires and were included in the sample. The percentage of innovative manufacturing firms compared to the total number of manufacturing firms are in line with the OECD report (2019). Therefore, we are aware that we only focused on the innovating 20% of our total population of manufacturing firms.

While the data was adapted in IBM SPSS statistics 26, RStudio was used to produce descriptive statistics and a correlation table for the variables. Besides, RStudio was used to execute the regression analyses. Descriptive statistics including a theoretical substantiation for each variable are provided in *Table 2.* As *Table 2* shows, the counts for both variables for knowledge spillovers are extremely skewed, which was why Pearson's regression analysis initially was preferred instead of standard OLS regression. Also, we found large distributions for our variables *EducIndex* and *GPNIndex.* Additionally to the descriptive statistics table, a correlation matrix was added including all variables in *Appendix 2.* While the variables *NatKnowSpil* and *IntKnowSpil* showed a quite strong correlation (Pearson's Cor.= .635), none of our variables correlated worryingly high. All the variables were suitable for analysis, since all the variables met the correlation requirements (Pearson's correlation <.90).

[8] Paragraph 3.2 provided detailed information which variables were converted from plant to firm level.

Table 2: Descriptive statistics for variables

Models 1-5						
Variables	*Mean*	*St.Dev.*	*Med.*	*Med.*	*Max.*	*Theoretical substantiation*
NatKnowSpil	3.64	3.95	2.00	0	23	*(e.g. Glaeser et. Al, 1992)*
IntKnowSpil	1.46	2.50	0	0	23	*(e.g. Kotabe et. Al, 2007)*
ImprProd	1.24	0.72	1.00	0	2	*(e.g. Gilbert et. Al, 2008)*
RedCom	0.42	0.72	0	0	2	*(e.g. Wang & Wang, 2012)*
ImprSust	1.31	1.22	1	0	4	*(Sezen & Cankaya, 2013)*
EducIndex	17.94	12.87	14.93	0	94.44	*(e.g. Foster-McGregor & Pöschl, 2016)*
NumbWork	238	395	90	2	4181	*(e.g Markusen & Trofimenko, 2009)*
Bogotá (D)	0.33	0.47	0	0	1	*(e.g. Boschma, 2005)*
Antioquía (D)	0.27	0.49	0	0	1	*(e.g. Boschma, 2005)*
Cundinamarca (D)	0.10	0.30	0	0	1	*(e.g. Boschma, 2005)*
GPNindex	11.52	16.75	1.31	0	81.38	*(e.g. Kraemer et. Al, 2005)*
PartGPN (D)	0.33	0.47	0	0	1	*(e.g. Kraemer et. Al, 2005)*

Source: Created by author

4. Results

This chapter presents the results that came forward from the five models that that were used to test the hypotheses. In the *Methodology & data description* it was then stated that this study used two separate sets of analyses. On the one hand, the first set of analyses focused on hypotheses 1-3, which are discussed in *Paragraph 4.1.* On the other hand, the second set of analyses focused on linking knowledge spillovers and GPNs to improved performance. Therefore, the results for hypotheses 4-5 are discussed in *Paragraph 4.2.* Both paragraphs first discuss the model, followed by each variable that was included in each set of analyses. Then, each paragraph links the results to the hypotheses for that set of analyses. The results for all five models are added in *Table 3,* which is presented at the next page:

Table 3: Results of analyses

Dependent variables:	Nat. knowledge spillovers	Int. knowledge spillovers	Improved productivity	Decreased com. costs	Improved sustainability
Regression method:	*Poisson*	*Poisson*	*Ordered logistic*	*Ordered logistic*	*Ordered logistic*
Model:	(1)	(2)	(3)	(4)	(5)
Education index	0.013¨	0.017¨			
	(0.001)	(0.002)			
Number of employees	0.0004¨	0.001¨			
	(0.00003)	(0.00003)			
Bogota (D)	-0.040	-0.090			
	(0.040)	(0.064)			
Antioquia (D)	0.258¨	0.241¨			
	(0.039)	(0.061)			
Cundinamarca (D)	0.078	0.257¨			
	(0.053)	(0.078)			
GPN index	0.002˙	0.018¨			
	(0.001)	(0.001)			
Nat. knowledge spillovers			0.002	0.062¨	0.065¨
			(0.017)	(0.019)	(0.017)
Int. knowledge spillovers			0.010	-0.060	0.003
			(0.029)	(0.032)	(0.027)
Participation in GPN (D)			0.339¨	-0.035	0.321¨
			(0.122)	(0.133)	(0.118)
Constant	0.837¨	-0.539¨			
	(0.037)	(0.061)			
Observations	1,249	1,249	1,249	1,249	1,249
Log Likelihood	-3,872.090	-2,439.770	-389.599	-338.222	-625.199
Akaike Inf. Crit.	7,758.181	4,893.541	789.197	686.445	1,264.398
Note:					˙p<.05 ¨p<.01

Source: Created by author

4.1 Characteristics of knowledge spillovers

In the *Methodology* it was mentioned that hypotheses 1-3 were covered by models 1-2. Therefore, the first two models are discussed in this paragraph. The first model for national knowledge spillovers found a significant relation with the independent variables based on a 99% confidence interval (LLhood=-3872.09, AIC=7758.18, p<.01). Based on the model we argue that there exists a positive correlation between the included variables on the total number of sources for nationally originated knowledge spillovers that were aggregated by each innovative Colombian manufacturing firm. Additionally, the second model for international knowledge spillovers also found a significant relation between the variables, which is again based on a 99% confidence interval (LLhood=-2439.77, AIC=4893.54, p<.01). Based on the results, we argue that there exists a positive correlation between independent variables and the number of obtained sources of international knowledge spillovers.

The results in *Table 3* indicate that some variables in the first model turned out to be significantly impacting the sources of national knowledge spillovers that were obtained for each manufacturing firm. Firms with a higher educated workforce are expected to aggregate more nationally originated knowledge spillovers [β=.013, p<.01. Moreover, it was found that the quantity of workers significantly impacted the number of obtained national knowledge spillovers [β=.0004, p<.01]. Both the number of workers and the number of high educated workers were significant based on a 99% confidence interval. Additionally, location matters regarding national knowledge spillovers. While firms in Bogota or Cundinamarca did not significantly generate more sources of knowledge spillovers, firms located in the department of Antioquia did. Firms that are in Antioquia are expected to generate around 26% more national sources of knowledge spillovers than firms with similar characteristics in other departments [β=.258, p<.01]. Besides, the degree in which firms participate in GPNs significantly impacted the number of acquired nationally originated knowledge spillovers based on a 95% confidence interval [β=.002, p<.05].

The second model about internationally originated sources of knowledge spillovers showed almost identical results for the variables that were concluded in the analysis. The results show that high educated workers [β=.017, p<.01] and the number of workers [β=.001, p<.01] both positively impact the number of sources for international knowledge spillovers. Both independent variables are significant based on a 99% confidence interval. Besides, location mattered again since Antioquia [β=.0241, p<.01] and Cundinamarca [β=.257, p<.01] as geographical locations positively impacted the number of sources for international knowledge spillovers. Both departments are significant based on a 99% confidence interval, while our variable for Bogota showed no significant relation with our dependent variable. For participation grade in GPNs, which is represented by *GPNIndex* in the models, we found that participation grade in GPNs positively influences the sources of international knowledge spillovers for innovative Colombian manufacturing firms [β=.018, p<.01]. Again, this relation is based on 99% confidence interval.

4.1.1 Results for hypotheses 1-3

- *Hypothesis 1.* Based on the results that came forward, hypothesis 1 is accepted for both nationally and internationally originated knowledge spillovers. Human capital has a positive effect on the sources of knowledge spillovers that are obtained for each Colombian manufacturing firm. While Foster-McGregor & Pöschl (2016) only found evidence for a relation between the labour mobility of a highly educated workforce and knowledge spillovers, we add that this relation exists on various scale levels, for a widespread sample of manufacturing firms. Besides education, the total number of workers showed significant results in both models. The results for the number of workers are in line with existing literature by Markusen & Trofimenko (2009).

- *Hypothesis 2.* Multiple sources stated that geography would influence knowledge spillovers at various scale levels (e.g. Audretsch & Feldman, 2004). Based on both models, we conclude that geography did impact knowledge spillovers. Therefore, hypothesis

2 is accepted. However, the results are only partially in line with literature obtained from academic journals and the Colombian national statistics bureau (DANE). Based on literature, it was expected that firms in Bogotá would generate at least more international knowledge spillovers based on its interconnectivity and inward FDI statistics. However, the results only found statistical confirmation for the other two departments which were Antioquia and Cundinamarca.

- *Hypothesis 3.* The third hypothesis suggested that the more internationally a firm operates, the more sources of knowledge spillovers it would generate. Based on the results we find that this is the case for both nationally and internationally originated sources of spillovers. Consequently, the third hypothesis is accepted. We state that our results are in line with Kraemer et al. (2005), while we add that this relation exists on multiple geographical scales.

4.2 Improved firm performance

In *Section 2.2.2* it was mentioned that three different measurements were used for improved performance as a result of innovation: *1) Improved productivity, 2) Reduced communication costs and 3) Improved sustainability.* The results for all three ordered logistic analyses were reported in *Table 3.* The results show that all three models turned out to be significant. The first model for improved productivity is significant based on a 95% confidence interval (LLhood=-389.60, AIC=789.20, p<.05). Then, the model for reduced communication costs is significant at a 99% confidence interval (LLhood=-338.22, AIC=686.45, p<.01), while the third model for improved sustainability showed similar results based on a 99% confidence interval ((LLhood=-625.20, AIC=1.264.40, p<.01).

When looking closer to the independent variables, in the model for improved productivity we find that neither nationally nor internationally obtained sources of knowledge spillovers showed significant relations with the dependent variable. However, firms who participated in GPNs positively affected the categorical class of improved productivity based on a 99% confidence interval [β=.399, p<.01] [9].

In the model for reduced communication costs, we find a higher number of nationally originated sources of knowledge spillovers positively impacts the category class in which firms have reduced their communication costs. This claim is based on a 99% confidence interval [β=.062, p<.01]. Neither internationally based sources of knowledge spillovers nor participation in GPNs significantly impacted reduced communication costs.

In the final model for improved sustainability, we find that a higher number of nationally originated knowledge sources has a positive impact on the level in which firms improved their sustainability through innovation. This relation is significant based on a 99% confidence interval [β=.065, p<.01]. Besides, we find that participation in GPNs positively impacts the level of improved sustainability, which is again based on a 99% confidence interval [β=.321, p<.01].

4.2.1 Results for hypotheses 4-5

- *Hypothesis 4.* The fourth hypothesis suggested that there exists a positive relation between sources of knowledge spillovers and improved firm performance through innovation. The results show positive relations for nationally originated sources of knowledge spillovers in models 5-6, while internationally originated sources did not show any significant relations with improved firm performance. For improved productivity no a relation is found for nationally nor internationally originated sources of knowledge

[9] We want to remind the reader that improved productivity is based on three classes (zero, small or large improved productivity.

spillovers. Therefore, hypothesis 4 is partly accepted, but remains very specific. One may consider these results to be in line with existing theory on knowledge spillovers and firm performance, as Glaeser et al. (1992) found such relation on the national level. We add to existing theory that national sources of knowledge spillovers influence only specific types of improved firm performance.

- *Hypothesis 5.* The fifth hypothesis suggested a positive relation between firms who participate in GPNs and improved firm performance. Based on the results, hypothesis 5 is partly accepted, since significant relations were found only in models 3 and 5. Existing theory stated that firms who participate in GPNs are often more productive (Kraemer et. al., 2005). Based on the results, we add to existing literature that participation in GPNs is positively related to an improved level of sustainability in our case study, which provides an interesting insight.

Conclusion & discussion

The purpose of this study was to research to what extent innovating Colombian manufacturing firms used sources of knowledge spillovers and whether those spillovers affected their firm performance. Besides, the focus was on comparing firms that either did or did not participate in GPNs. Theory by Barrientos et. al. (2018) claimed that, for firms who participated in GPNs, improved firm performance may result to economic upgrading in these international networks. Based on the results that were found through various analyses, we conclude that firms who participate in GPNs in general significantly benefit more as they innovate compared to firms that do not participate in GPNs. More specifically, firms in GPNs are more likely to improve their productivity and sustainability through innovation compared to firms that do not participate in GPNs. Besides, for knowledge spillovers, we argue that national knowledge sources contribute to improved firm performance, while we did not find any relation for internationally originated knowledge sources.

In our introduction we claimed that this study would contribute to science by providing more specific insight how the main concepts, GPNs, knowledge spillovers and firm performance, are connected to each other. Among others (Coe et. Al, 2004), claimed that firms in GPNs should strategically couple between the international, national and regional scale levels in order to be most successful. Based on our results, we conclude to agree with this theory. Firms who strategically use local knowledge sources, while being embedded in global networks, benefit more as they innovate compared to firms that do not meet these characteristics. Therefore, we claim that this study found a more detailed example how firms strategically couple different sources of knowledge spillovers. Besides, our study provided a detailed overview how sources of knowledge spillovers on different levels are related to three forms of improved firm performance. It was concluded that there exist differences between the three types of improved firms' performance, while science suggests many more forms of firm performance. Therefore, we suggest that a more specified study for other types of firm performance would be interesting for future research. Besides, this study successfully contributed to science by providing insight how GPNs and knowledge spillovers impact firm performance in a relatively less researched, rapidly developing country such as Colombia.

Then, the introduction stated that the results may be useful for policy advisors in rapidly developing countries such as Colombia. The results show that nationally originated knowledge spillovers and participation in GPNs affect the chance that manufacturing firms benefit from innovations. Policy makers may encourage manufacturing firms to become increasingly embedded in GPNs. Besides, policy makers can organize meetings, fairs or other activities that provide possibilities for knowledge spillovers to spread among firms. Additionally, it was stated that the results may be helpful for manufacturing firms. Based on the results, we recommend manufacturing that firms that want to obtain more knowledge spillovers to focus on human capital and participation in international networks, while they should keep in mind that their geographical location matters.

Though, this study had some limitations. Colombia is a vast and diverse country. While some areas include vast territories of rain forest or mountains, some areas feature large cities such as Bogotá, Medellín and Cali. Therefore, we argued the importance of a geographical component in our data. However, all geographical data that was included in the datasets were based on the department level. As departments combined cities with vast 'empty' rural territories, we were not able to define an urban rural comparison. Therefore, we suggest that it would be relevant for future studies to provide insight in a similar case study with a geographical component on the municipal or county level. We expect geographical impact to be stronger when comparing manufacturing firms on a smaller geographical scale.

Also, the data is anonymously selected from firms that pay tax to the Colombian government. Unfortunately, the data did not provide information about the national or international origin of each manufacturing firm. If we would have been able to detect the firm's origin, the indicator about participation in GPNs would have changed. For example, we would have been able to separate MNEs from a Colombian or foreign origin. Also, manufacturing firms were not categorized based on their sector or type of industry. We opted for a more general study, since we did not find any differences when we compared for different types of industries. However, various sources claimed sector-specific differences for economic upgrading in GPNs (e.g. Barrientos et. al., 2011), which should still be taken into account. Besides, many existing theories on knowledge spillovers focuses on labour mobility as its main source (e.g. McCann & Simonen, 2005). While this study provided insight to other sources of knowledge spillovers, it would have been relevant to find how knowledge flows from expats into rapidly developing economies such as Colombia.

Additionally, in the *Methodology* it was stated that we were unable to use all cases after we merged the datasets. Since data on firm performance and knowledge spillovers was only available for manufacturing firms that innovated in 2018, we were forced to leave out 80% of our cases (DANE, 2019). Therefore, we were unable to compare our results with firms that were not innovative in 2018 or to generalize for all Colombian manufacturing firms. Also, improved firm performance was measured based on categorical variables. The datasets that were used in this study did not provide enough data to quantify improved productivity, reduced communication costs nor improved sustainability. Therefore, we were forced to execute ordinal logistic regression analyses. A quantified variable for firm performance would have been more suitable, which we therefore recommend to use in further research.

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Appendices

Appendix 1: Explanation for sources of knowledge spillovers

Knowledge source (Nat. or Int.)	Name in equations
1.Intra-firm R&D	IfR&D
2. Intra-firm (except R&D)	IfnR&D
3. Customers	Cust
4. Suppliers	Sup
5. Intra-firm (other sectors)	IfOs
6. Business associations	BusAs
7. Chambers of commerce	ChCom
8. Technological development centers	TechDev
9. Technological incubator firms	TechInc
10. Technological parcs	TechPar
11. Regional production parcs	RegProdPar
12. Universities	Uni
13. Training centerswew	TrainCen
14. Consultants or other types of experts	ConsExp
15. Fairs & exhibitions	FaEx
16. Seminars & conferences	SemCon
17. Books and journals	BoJo
18. Patent databanks	PaData
19. Copyright information systems	CopInSys
20. Internet pages	IntPag
21. Scientific databases	ScienDat
22. Technical standards and regulations	TechStReg
23. Public institutions	PubInst

Source: EDIT in (DANE, 2019) – Created by author

- Equation for national originated sources:

$$NatKnowSpil_i = IfR\&D_i + IfnR\&D_i + Cust_i + Sup_i + IfOs_i + BusAs_i + ChCom_i + TechDev_i + TechInc_i + TechPar_i + RegProdPar_i + Uni_i + TrainCen_i + ConsExp_i + FaEx_i + SemCon_i + BoJo_i + PaData_i + CopInSys_i + IntPag_i + ScienDat_i + TechStReg_i + PubInst_i$$

in which i represented each individual firm's variables with a national origin.

- Equation for international originated sources:

$$IntKnowSpil_i = IfR\&D_i + IfnR\&D_i + Cust_i + Sup_i + IfOs_i + BusAs_i + ChCom_i + TechDev_i + TechInc_i + TechPar_i + RegProdPar_i + Uni_i + TrainCen_i + ConsExp_i + FaEx_i + SemCon_i + BoJo_i + PaData_i + CopInSys_i + IntPag_i + ScienDat_i + TechStReg_i + PubInst_i$$

in which i represented each individual firm's variables with an international origin.

Appendix 2: Correlation matrix for variables in models 1-5

Correlations & variables		NatKnowSpil	IntKnowSpil	ImprProd	RedCom	ImprSust	EducIndex	NumbWork	Bogota	Antioquia	Cundinamarca	GPNindex	PartGPN
NatKnowSpil	P.Cor	1	.635**	0.036	.075**	.160**	.171**	.240**	-.083**	.109**	0.022	.098**	.179**
	Sig.		0.000	0.200	0.008	0.000	0.000	0.000	0.003	0.000	0.446	0.001	0.000
IntKnowSpil	P.Cor	.635**	1	0.049	0.005	.129**	.202**	.351**	-.091**	.064*	.063*	.288**	.348**
	Sig.	0.000		0.083	0.864	0.000	0.000	0.000	0.001	0.025	0.025	0.000	0.000
ImprProd	P.Cor	0.036	0.049	1	.235**	.374**	-0.023	.059*	-0.049	-0.009	0.015	0.020	.089**
	Sig.	0.200	0.083		0.000	0.000	0.416	0.038	0.085	0.757	0.605	0.474	0.002
RedComC	P.Cor	.075**	0.005	.235**	1	.458**	0.034	0.009	.073*	-0.021	-0.017	-0.017	-0.004
	Sig.	0.008	0.864	0.000		0.000	0.231	0.741	0.010	0.461	0.553	0.544	0.890
ImprSust	P.Cor	.160**	.129**	.374**	.458**	1	0.022	.119**	-0.017	-0.024	0.009	.057*	.118**
	Sig.	0.000	0.000	0.000	0.000		0.431	0.000	0.555	0.404	0.745	0.043	0.000
EducIndex	P.Cor	.171**	.202**	-0.023	0.034	0.022	1	0.047	.066*	-.122**	.057*	.210**	.222**
	Sig.	0.000	0.000	0.416	0.231	0.431		0.095	0.019	0.000	0.044	0.000	0.000
NumbWork	P.Cor	.240**	.351**	.059*	0.009	.119**	0.047	1	-.146**	.077**	0.046	.208**	.365**
	Sig.	0.000	0.000	0.038	0.741	0.000	0.095		0.000	0.006	0.105	0.000	0.000
Bogota	P.Cor	-.083**	-.091**	-0.049	.073*	-0.017	.066*	-.146**	1	-.431**	-.236**	-.058*	-.107**
	Sig.	0.003	0.001	0.085	0.010	0.555	0.019	0.000		0.000	0.000	0.039	0.000
Antioquia	P.Cor	.109**	.064*	-0.009	-0.021	-0.024	-.122**	.077**	-.431**	1	-.207**	-0.007	-0.010
	Sig.	0.000	0.025	0.757	0.461	0.404	0.000	0.006	0.000		0.000	0.812	0.732
Cundinamarc	P.Cor	0.022	.063*	0.015	-0.017	0.009	.057*	0.046	-.236**	-.207**	1	-0.005	.091**
	Sig.	0.446	0.025	0.605	0.553	0.745	0.044	0.105	0.000	0.000		0.854	0.001
GPNindex	P.Cor	.098**	.288**	0.020	-0.017	.057*	.210**	.208**	-.058*	-0.007	-0.005	1	.627**
	Sig.	0.001	0.000	0.474	0.544	0.043	0.000	0.000	0.039	0.812	0.854		0.000
PartGPN	P.Cor	.179**	.348**	.089**	-0.004	.118**	.222**	.365**	-.107**	-0.010	.091**	.627**	1
	Sig.	0.000	0.000	0.002	0.890	0.000	0.000	0.000	0.000	0.732	0.001	0.000	

Pearson's correlation matrix. Significance levels: *=p<.05, **=p<.01

Source: Created by author