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Foreign Direct Investment, Technological Advancement, and Absorptive Capacity: A network Analysis

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Résumé

Des innovations en technologie sont considérées un instrument important pour le développement économique et technologique, mais la plupart des pays bénéficient d’innovations et de nouvelles technologies par le transfert des technologies. L’IDE (Investissement Direct à l’étranger), parmi les autres moyens, est fréquemment utilisé pour diffuser la technologie, mais les savants typiquement considèrent les liens directs pour comprendre l’avancement technologique des technologies sans mettre trop l’importance aux liens indirects ou l’interconnectivité parmi les pays. De plus, des études précédentes suggèrent que l’IDE n’est pas également distribuée parmi tous les pays et qu’un pays doit avoir une capacité d’absorption pour bénéficier du transfert des technologies par l’IDE. Pour enrichir la connaissance sur comment la technologie diffuse par l’IDE, cette thèse utilise une façon- analyse du réseau-basée sur le modèle- l’IDE bilatéral parmi des pays est un réseau interdépendant pour la période 2009-2016. Cette recherche révèle la preuve empirique que le réseau global de l’IDE a une structure-noyau-périphérie- et que les pays du noyau sont plus développés en technologie plutôt que les pays périphériques. Cette recherche également suggère que la position d’un pays dans le réseau de l’IDE est positivement associée avec la condition technologique de ce pays. Néanmoins, cette recherche révèle le support partial que la capacité d’absorption-mesurée par l’intensité de connaissance, le capital humain, et la R&D (recherche et développement) -peut modérer positivement le lien entre la position sur le réseau d’un pays et la condition de technologie du pays. Un résultat intéressant de cette recherche est l’importance de l’intensité de connaissance dans la condition technologique d’un pays. Ce résultat permet de mieux comprendre la capacité d’absorption.

Mots-clés

Transfert des technologies, analyse de réseau, investissement direct à l’étranger, capacité d’absorption

Abstract

Technological innovation is considered an important instrument for economic and technological development, but most countries get the benefit of innovation and new technologies through technology transfer and technology absorption. Foreign Direct Investment (FDI), among other channels, is frequently used to transfer technologies, but scholars typically consider direct linkages to understand technological advancement without much attention to the indirect linkages or interconnectivity among countries. In addition, earlier studies suggest that FDI is not equally distributed among all countries, and a country must have a sufficient level of absorptive capacity to benefit from technology transfer through FDI. To extend knowledge on how technology diffuses through FDI, this thesis uses a network analysis approach and models bilateral FDI among countries as an interdependent network for the period 2009-2016. The research finds empirical evidence that the global FDI network has a core-periphery structure and core countries are more technologically developed than peripheral countries. The research also finds empirical evidence that a country's position in the FDI network is positively associated with that country's technology status. However, the research finds partial support that a country's level of absorptive capacity - measured in terms of R&D, human capital, and knowledge intensity – positively moderates the relationship between a country's network position and technology status. An interesting finding in this research is the significance of knowledge intensity in technology status of a country. This finding gives a nuanced understanding of absorptive capacity.

Key words

Technological advancement, network analysis, foreign direct investment, absorptive capacity

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List of abbreviations

FDI = Foreign Direct Investment

NRR = Networked Readiness Ranking

R&D = Research and Development

GDP = Gross Domestic Production

IMF = International Monetary Fund

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1. Introduction

Technological innovation has long been considered an important instrument for economic and technological development (Hofmann, 2013; Findlay, 1978; Xu, 2000; Lall and Narulla, 2004; Volberda et al.,2010). Porter (1990) mentions innovation as the key to obtaining competitive advantages. In support of Porter's view of innovation and competitive advantage, Grossman and Helpman (1993) provide evidence on the role of technology in economic growth and development with a focus on industrial innovation, and they view innovation as a natural outcome of industrial research by forward looking agents.

However, innovating technology is costly and not all countries can afford to implement it. For instance, Mudambi (2008) and Van Assche (2014) mentioned that high value-added activities such as R&D and marketing are usually kept in developed countries. Similarly, Keller (2004, 2010) says that technological innovation takes places only in a few high-income countries, while foreign sources of technology account for 90% or more of the domestic productivity growth for other middle-income and low-income countries. These circumstances suggest that other countries get the benefit of innovation and new technologies through the transfer of technologies from developed countries.

***Tung (1994) draws attention to two dimensions of technology transfer: technology transfer focused on the supply side - the willingness and ability of the innovator and the supplier; and technology transfer focused on the demand side – assimilation by the recipients over time and space. Technology transfer focused on the demand side is more about the diffusion of technology. However, there is no clear boundary between transfer and diffusion.

Technology diffusion, technology transfer, knowledge transfer, and knowledge spillover have been used in various studies to explain technology transfer and absorptive capacity. Thus, this research uses the terms interchangeably.

Foreign Direct Investment (FDI), among other channels, is frequently used to transfer new technologies (Blomstrom and Kokko, 1999; Borensztein et al., 1998; Baranson, 1970; Gorg and Greenaway, 2004) because FDI is less volatile compared to other financing sources and is an important vehicle for technology transfer without any risk of leakage (Lall and Narula, 2004). Moreover, due to the tendency toward global economic integration, countries are becoming more willing to open their economies to foreign investors (Lall and Narula, 2004).

Despite the role of FDI in technological advancement and academic interest in this topic, there has been little research on FDI networks, even less in the country level networks. Researchers, so far, have used industry level or firm level data to measure spillover effects from FDI with mixed results. In the firm level studies, the MNEs have been perceived as a network of geographically and organizationally dispersed subsidiaries, and a network approach is suggested to be a useful tool to study the nature and complexity of an MNE - specifically the roles of subsidiaries and dispersal of MNEs' resources among subsidiaries (Ghoshal and Bartlett, 1990, Schoeneman et al., 2017). In the country level, nearly all of such studies were single country case studies. Though single-country studies might better capture the outcome of foreign presence in a country's economic and technological development, these results are country-specific and difficult to generalize.

On the other hand, researchers typically consider the direct linkages among countries to measure technological advancement (Liu and Wang, 2003; Helpman, 1997; De La Potterie, 2001; Xu, 2000; Girma, 2005; Khalifah et al., 2015) and do not emphasize the indirect linkages among countries, for instance, the inter-connectivity of the recipients of FDI. Thus far, no study has been done to understand the transfer of technology through the global FDI network by using a network analysis approach. Therefore, the purpose of this research is to apply network perspectives to get a more nuanced understanding of the relationship between the global FDI network and the technological advancement of a country.

Network analysis allows us to examine the interaction and the structure of a relationship among the related parties and to understand the role of networks in different areas. It has been effectively used in a number of studies such as transfer of ideas, disease, pollution, etc. (Goyal, 2012; Jackson, 2008; Albert and Barabasi, 2002) The most recent use of network analysis approach in International Business literature are such examples as Ferrier et al. (2016) who analyze the effect of the trade network in technology transfer and find that in most cases, countries that are better connected to the trade network have higher technology intensity, or Turkina and Van Assche (2018) who explore the effect of inter-cluster networks on cluster innovation and find that cluster-network position has important implications for innovation.

Even though network perspective in FDI can give us a powerful understanding of a country's position in the FDI network and its effect in technological development, the relationship between technological advancement and FDI is not really straightforward. For instance, Khalifah et al. (2015) report that FDI has both positive and negative spillover effects on the domestic establishment. Similarly, Ferragina and Mazzotta (2014) provide evidence that high technology firms do not benefit from horizontal FDI as do low and medium technology firms. Thus, receiving FDI does not guarantee access to advanced technology. Earlier studies (Baranson, 1970; Ferragina and MAzzota, 2014; Girma, 2005;

Marin and Bell, 2006 among others) suggest that recipients must have some capabilities to absorb the accompanying technology. Absorptive capacity of the sender and receiver, the past experiences, and the degree of prior related knowledge are some of the most important factors influencing the success of knowledge transfer (Volberda et al.,2010). Therefore, this research will explore the moderating features of absorptive capacity measured in terms of R&D, human capital, and knowledge intensity.

This thesis has a multifaceted contribution. First, this it contributes to theory by complementing the limited existing International Business literature on network analysis with a particular focus on the FDI network to understand the structure of the global FDI network. Second, the analysis supplements the existing literature on FDI and technological advancement with quantitative evidence. Third, it provides insights to enable host countries to formulate better policies so as to catch up to technologically developed countries.

The remainder of the thesis is structured as follows: In the next section, literature related to FDI, technology transfer, technological advancement, network analysis, innovation systems, and absorptive capacity is reviewed to develop hypotheses. Three variables – namely, R&D, human capital, and knowledge intensity are identified in this section as determinants of absorptive capacity that possibly moderate the process of technological advancement through FDI. The subsequent section describes the data and research methodology. The research then reports and discusses the results. Finally, the thesis concludes by discussing the limitations of the analysis and suggesting future research directions as well as highlighting the contributions of this research in the literature.

2. Literature review and hypotheses development

This research reviews the literature with a focus on technology transfer and technological advancement through FDI and elaborates the studies that are more relevant. First, there is an overview of the concepts used in this research to provide a better understanding of FDI, technology and technological advancement, absorptive capacity, and network analysis. Later, the thesis reviews the studies that use network analysis in the context of international exchanges. Finally, based on the reviewed literature, the research develops hypotheses about the structure of the global FDI network; the relation between network position and technology level; and the role of absorptive capacity in deriving the benefit from FDI and its attendant technology.

2.1 Overview of concepts and theories: Foreign Direct Investment, technology, network analysis, and absorptive capacity

2.1.1 Foreign direct investment

Foreign Direct Investment is a category of cross-border investment made by a resident in one economy with the objective of establishing a lasting interest in an enterprise that is resident in an economy other than that of the direct investor (OECD, 2008; IMF, 2003). The motivation of the direct investor is a strategic long-term relationship with the direct investment enterprise to ensure a significant degree of influence by the direct investor in the management of the direct investment enterprise, and the investors are eager to establish a research facility closer to the foreign research cluster to acquire knowledge of research status quo (ibid).

Direct investment may also allow the direct investor to gain access to the economy of the direct investment enterprise that might otherwise difficult if not impossible. For instance, investors' motive for investing abroad, as mentioned by Hofman (2013), is to gain access to the foreign firm's knowledge and technology. Beyond that, FDI can affect the management of international business networks (Pisano and Shih, 2009). FDI helps to maintain an uninterrupted supply chain and value chain as well as giving entry to different markets.

FDI has always been considered an important source of financing. During the 1990's, FDI became the largest single sources of external financing for developing countries. In 1997, FDI accounted for about half of the private capital and two-fifths of the total capital flow in developing countries. Though the FDI flow has been somewhat bumpy during the last decade and lost momentum in 2016 with a 2% decrease in FDI inflow, FDI still remains the largest and most constant external source of financing for developing economies - compared with portfolio investments, remittances, and official development assistance (UNCTAD – World Investment Report, 2017).

Dunning (1988, 2001) gives the most popular explanation, known as OLI advantages, of when and how MNEs decide to internationalize in the "Eclectic Paradigm of International Production". Dunning classifies the required elements as ownership advantages, location advantages, and internalization advantages. Ownership advantages are the firm-specific advantages such as possession of assets, mainly intangible, that are exclusive to the firms and not available to competitors. Location advantages are determined by the comparative or competitive advantages of specific locations and focus on the benefit of combining the movable assets of the home countries with partially or totally immovable assets of the host countries. Internalization advantages are about deciding whether to produce in-house to avoid market imperfections and are decided by coordination and transaction costs. According to eclectic theory of FDI, MNEs arise from exploiting the advantages of internalizing firm-specific assets and choose to invest in a location that allow them to best capitalize such assets.

Another important theory which explains the internationalization of firms is the concept of transaction cost economics (TCE). Coase (1937) and Williamson (1989, 2005) explain that different types of costs are involved in the coordination of the activities and risks in a transaction in a foreign country. Coase (1937) and Williamson (1989, 2005) emphasize that lack of properly functioning institutions and perfect markets increase transaction costs and lead MNEs to internalize their production activity.

MNEs has also been the focus of interorganizational theory or network theory in which MNEs have been perceived as a network of geographically and organizationally dispersed units and studied to understand the transfer of resources among different units (Ghoshal and Bartlett, 1990; Schoeneman et al, 2017). Within the MNE network, an actor can enhance its power by connecting with other actors and use such power to attract resources (Ghoshal and Bartlett, 1990; Benson, 1975) suggesting that the better-connected units will have more power and resources.

Consequently, by operating in different locations, MNEs are better positioned to build strategic partnerships and networks with customers, suppliers, universities, and other research institutes. Moreover, in recent years, the affiliates of MNEs have come to play a more active role in global innovation networks by focusing more on core competencies and doing basic research (Bruche, 2009).

2.1.2 Technology

The term “technology” is an inherently abstract concept which is difficult to interpret, observe, and evaluate (Blomstrom and Kokko, 1999). Studies on technological advancement generally connect technology with knowledge and emphasize the role of R&D in generating and developing technological knowledge (Dunning, 2001). According to Pavitt (1985), technology is mainly differentiated knowledge – it can be both tacit and codified - about specific applications within firms. Based on this argument, technology can be viewed as firms’ intangible or firm-specific assets which form the basis of their competitiveness (Dunning, 2001). Technology, in terms of a firm’s intangible assets, is rooted in the firm’s routine and is not easy to transfer due to the gradual learning process and higher cost associated with transferring tacit knowledge (Radosevic, 1999).

Arthur (2009) says that a technology is based on some phenomenon or truism of nature that can be exploited and used to purpose. In his view, technology is built upon some existing principles for the purpose of accomplishing something in a new or in efficient way. Enos (1989) defines technology as technical information contained in patents and technical knowledge communicable in written forms. Similarly, Sollow (1999) defines technology as a knowledge that is embodied in a product or process and is easily available to the producer and consumer.

Technology can take various forms depending on its nature. Though Keller (2010) says that technology is an intangible and difficult to measure, there are indirect approaches that are able to define and measure technology. For instance, Radosevic (1999) suggests that technology includes knowledge about specific applications that may or may not easily reproducible or transferrable. Radosevic (1999) points out that technology can exist not only as disembodied and codified technical information but also as embodied knowledge.

Thus, the generation and transfer of technologies are the processes that vary according to forms and channels. Technology can be considered as both information and knowledge - it can exist in disembodied form such as patents and licenses or can be embodied in machines and persons. Examples of embodied technologies include blueprints and kind of information that can easily be transferred from the producers to the consumers. Likewise, technology can also be the knowledge about specific application that is not easily transferrable.

In the context of international business, technology can be the specialized knowledge and skills of a firm such as a specific design, plan, formula, or mechanism of accomplishing a task, which the firm does not want to share with others (Dunning 1988, 2001). The innovator firm can get a patent and exclude others from using such knowledge. Other firms can get access to this specialized knowledge either through contractual agreements or through spillover (Keller, 2004; Baranson, 1970).

The firm-specific characteristic of technology implies that technology is highly localized and provides specific advantages to a firm (Dunning, 2001; Radosevic, 1999). This particular nature of technology makes the transfer of technology difficult. Conversely, when technology is viewed only as information, it becomes easily transferrable. Although developing technology is costly, it can be transferred with minimal cost once created (Radosevic, 1999; Keller, 2004). The important issue in this case is the incentives to transfer and access technology.

However, there is no clearly defined way to measure technology because of its intangible nature (Keller, 2010; Sinani and Meyer, 2004; Cave, 1996). Besides, there are barriers and constraints to obtain latest technologies, too (Rauch, 2001) which creates inequalities between the developed and developing countries. Developing countries can neither develop technology on their own nor are they in a position to spend a large sum of money to obtain a license to access latest technology. In this circumstance, different types of international networks can pave the way for developing countries to access advanced technology through indirect linkages.

In addition, technology is making it ever more feasible to establish a business in one place and connect to tech hubs in other places (Amin and Cohendet, 2005), which suggests that tech companies thrive on network effects. This particular nature of technology gives ground for a network analysis to understand technology transfer and technological advancement, and the global FDI network is the most fitting network according to relevant literature. Thus, a network analysis will be instrumental – by accounting for both direct and indirect relationship – to better understand the role of FDI in technological advancement of a country. Following sections discuss the issues in detail.

2.1.3 Network analysis

A network is a mathematical description of the state of a system, at a given point in time, in terms of nodes and links (Schiavo et al., 2010). For instance, in this research, the network approach depicts countries as the nodes and the existence of an FDI relationship between any two countries as network linkages. The simplest type of network can be explained as a binary and undirected graph in which any two nodes can be either connected by a link or not, and link directions are unimportant (Schiavo et al., 2010). This thesis considers only binary networks – graphs where the mere presence or absence of an interaction between any two nodes is considered, not the actual value of the FDI linkages.

Jackson (2008), in “Social and economic networks”, gives a cogent overview of the network and defines a network as an undirected graph where two nodes are either connected or not. The nodes might be individual people, organizations, or countries. Jackson (2008) explains a model with different nodes where any two nodes have the same probability to be linked. Jackson (2008) defines any point in the network as a node, and states that a node can be connected to several other nodes, which is known as the degree of that particular node. Degree distribution of a random network gives an idea of a network’s structure and describes the probability that any given node will have a degree in terms of the number of connections it has (ibid).

For instance, let us assume that there are five countries – P, Q, R, S, and T. Now, consider that country P is a technologically advanced country and has a trade relationship only with country T. On the other hand, T is a developing country and has trade relationships with all four countries.

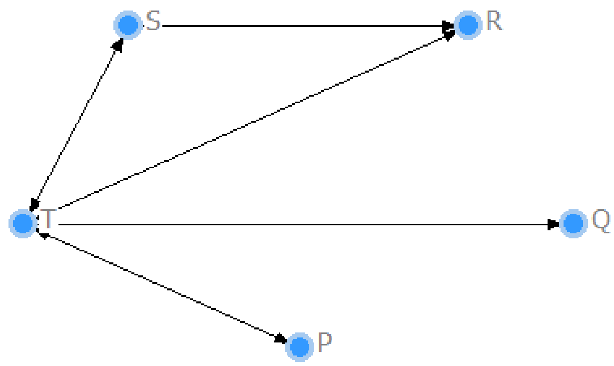


Figure 1: Illustration of a network

Most of the literature that considers direct trade relationship between countries would conclude that technology can at best be transferred from country P to country T, as other countries do not have access to country P’s technology. However, network analysis considers the indirect relationships among countries and suggests that the countries Q, R, and S could still gain access to country P’s technology through country T. In this network, country T completes the gap in the network by bringing all the countries together and thus has an important position. Position in the network is important regardless of whether it is fortuitous or strategic (Jackson, 2008). In this case, T is exposed to knowledge relevant to products or processes of all four countries through business relationship. The aggregate knowledge of country T may not be as advanced as country P, but the knowledge will be quite substantial.

The most prominent example of network relationship is detailed in the 15th century Florentine Marriage and rise of Medici who has been called the “Father of Renaissance”. His rise and accumulation of the power in the early 15th century Florence was of research interest for several scholars (Jackson, 2008; Padgett and Ansell, 1993). At that time marriage was the main form of communication and way of maintaining social and political alliances among elite families. Medici family was in the central position of this relationship. The reason behind the central position of Medici, and the other family's not trying to circumvent this particular family and forming more ties provide insights for a network structure.

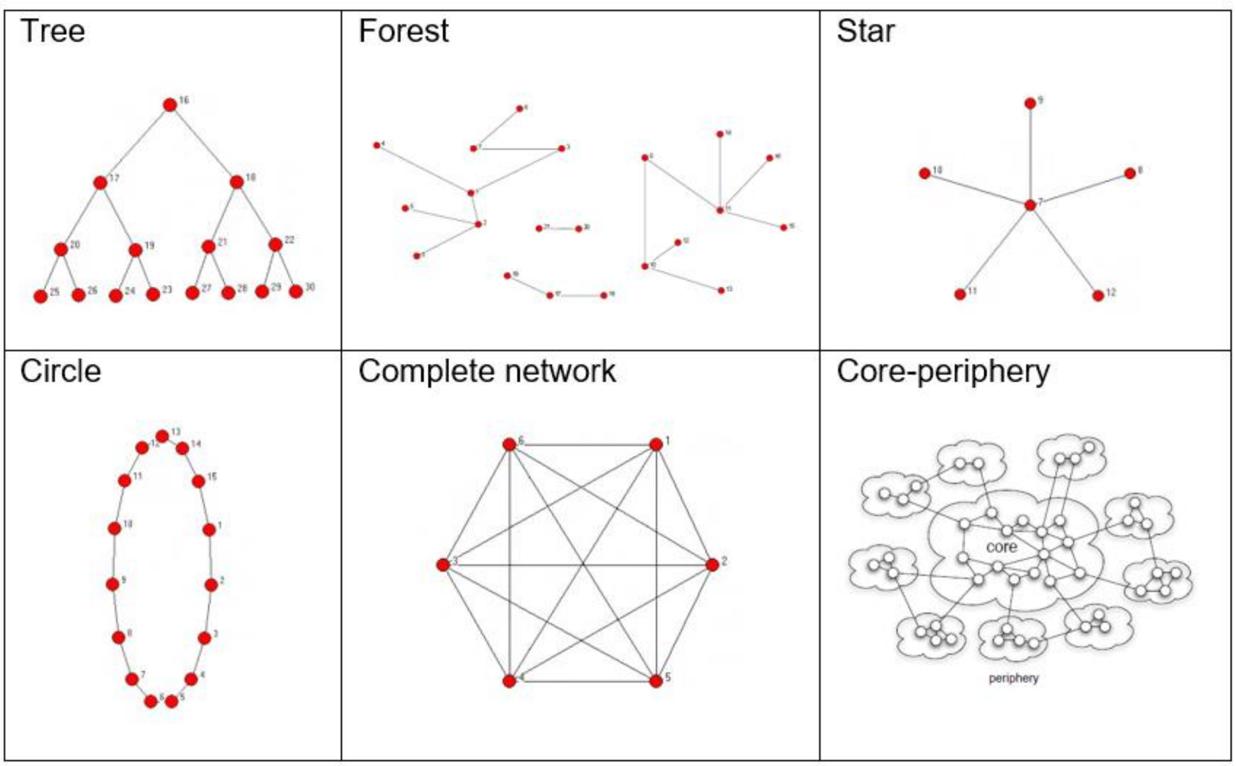
Jackson and Rogers (2005) examine the economic incentives of agents to form links and present a model in which network formation varies with the self-interest of agents. The fundamental economic reasons for network formation in their model, are the low cost of attachment to similar or nearby nodes and the large benefit of attaching to dissimilar or distant nodes. Jackson and Rogers (2005) suggest that though the connection between distant nodes would be limited because of high cost, such connections provide indirect access to other distant nodes, and benefit obtained from such indirect relationship may sometimes outweigh the cost of connection.

By analyzing any network, we can have insights into the association between network structures and actors' behavior and which structures are likely to emerge in a society. Further, this analysis would help in predicting and preventing future issues (Goyal, 2012). One major benefit of using network analysis is that it is able to capture both the direct and indirect relationship among the points in a network while most other quantitative analysis captures only direct relationships (Ferrier, 2015; Kali, 2007).

However, it is not always easy to summarize a network and its effects in a brief and clearly expressed way. There could be different structures in a network – some of the connections could be closely connected while some other connections could be sparsely positioned. Linkages in a network could either be randomly or strategically formed (Newman, 2010).

Though a network can be formed in different forms and shapes, there are a few particular network structures that are commonly referred to: a tree - is a connected network that has no cycles; a forest - is a network in which each component is a tree - in other words, any network that has no cycles is a forest; a star - is a network in that there exist some common nodes that are involved in every link of that network; a circle - is a network in that the network has a single cycle and every node is connected to exactly two nodes; a complete network – is a network in that all possible links are present (Jackson, 2008). Another well-known network structure is core-periphery structure. “Large social networks tend to be organized in a core-periphery structure, in which high status people are linked in a densely connected core, while the low status people are atomized around the periphery of the network” (Easley and Kleinberg, 2010).

Figure 2: Common network structures (Jackson, 2008; Easley and Kleinberg, 2010)



A network can be either efficient or inefficient with regard to the cost of maintaining connections and resulting benefits (Jackson, 2008). According to Jackson (2008), an efficient network is the one that maximizes the total utility for all nodes, and network structure varies with the cost. Jackson (2008) also notes that a network can be stars if the cost is in the middle range, empty if the cost is high, or complete if the cost is low, where a star is a network in which every link in that network involves a particular node. This situation gives an idea of the costs and benefits associated with network formation.

Random networks can be considered the simplest realization of complex networks in which the players are connected to each other without following any specific rule (Albert and Barabaasi, 2002). However, this is not always true for social and the economic networks. Real networks are far from being random, with organizing principles and specific structures (Albert and Barabasi, 2002). Though real social and economic networks are not random, understanding the structure of a random network provides insight into the structures of other social and economic networks. Considering the flow of FDI among of countries as a global network will give us a better understanding of the effect of a real network.

2.1.4 Absorptive capacity

Network relationship is a necessary but not a sufficient condition for transfer of technology. Even if the channels of technology transfer are present, recipients' qualities are important. A country will not be benefited from network relationships if that country does not have necessary capacities to exploit the technology. Moreover, such capacity can moderate the effect of the relationship between network linkages and technology. Amesse & Cohendet (2001) point out that the quality of technology transfer process is heavily dependent on the absorptive capacity of the recipients.

The premise of the idea of absorptive capacity is that the recipients need prior related knowledge to assimilate and use a new knowledge. Absorptive capacity is known as a recipient's ability to identify, assimilate, and exploit knowledge coming from different relationships (Cohen and Levinthal, 1989). Although Cohen and Levinthal (1989) use R&D spending as a firm level proxy for absorptive capacity, they suggest that other mechanisms such as the external sources of knowledge, socialization capabilities, and connectedness can also affect a firm's absorptive capacity.

Similarly, Lane et al. (2006) suggest three process dimensions – explorative learning, transformative learning, and exploitative learning – of absorptive capacity. Absorptive capacity has been studied from various perspectives such as competitive advantages (Cohen and Levinthal, 1990), innovation (Stock et al., 2001; Kostopoulos, 2011), interorganizational learning (Lane et al., 2001), knowledge transfer (Gupta and Govindarajan, 2000).

Though a firm's absorptive capacity depends on the absorptive capacities of its individual members, a firm's absorptive capacity is not simply the sum of the absorptive capacities of its employees (Cohen and Levinthal, 2000). There are other organizational aspects of absorptive capacity – it refers not only to the acquisition and assimilation of information by the recipients but also to the recipients' ability to exploit it (Cohen and Levinthal, 1989). Defining the complementarity of factors as absorptive capacity is a complex task, and such complementarity depends on the relative requirement of each recipient (Ritchie, 2002; Cohen and Levinthal, 1989).

Companies with specialists, qualified technicians, scientists, engineers, and staff with experience in specific areas are noted to have more absorptive capacities (Gupta and Govindarajan, 2000; Zahra and George, 2002). Narula and Marin (2003) also find that recipients that have larger investment in absorptive capacity can more efficiently internalize the knowledge coming through spillover. Thus, the relationship between FDI and technology development can be moderated by the level of the recipients' absorptive capacity (Nieto and Quevedo, 2005).

Hence, benefits from FDI depends on types of activities undertaken and absorptive capacities of a country, and such capacities are fundamental for getting indirect benefit from FDI (Baranson, 1970; Crespo and Fontura, 2007). In addition, absorptive capacity is the determinant of local capability, and the recipients need to actively integrate into the process of international technology transfer in order to get the most out of it (Ernst and Kim, 2002: Bodman and Le, 2013; Gugler and Brunner, 2007). Girma (2005) finds that absorptive capacity can enhance the benefit from FDI related technology, but the benefits of FDI can be positive, negative, or neutral depending on the respective countries' absorptive capacity. Moreover, the role of FDI seems to be country specific depending on the economic, institutional and technological conditions in the recipient countries (Ayanwale 2007; Amin and Cohendet, 2005; Girma, 2005).

Despite the proliferation of studies, research still lacks empirical comprehension regarding key theoretical assertions on the relationship between knowledge inflows and technological advancement (Kostopoulos et al., 2011). The existing literature recognize R&D and human capital as determinants of absorptive capacity. Some studies also emphasize the role of spatial knowledge in improving local knowledge base. Thus, this thesis uses R&D, human capital, and knowledge intensity as the determinants of absorptive capacity in the country level. These determinants are elaborated in later sections.

Now that the concepts used in this thesis have been discussed, the following section reviews the studies about different types of networks in international arena.

2.2 Networks in international arena: an overview

Understanding the linkages and structures of a network allows us to predict behaviors of the participants in a range of situations such as diffusion of information, pollution, and spread of diseases. It also provides important insights into the way the participants are motivated to behave in a specific situation. For example, the structure of a trade network may be determined by, among other things, the behavior of trading partners and opportunities and threats in the relevant markets.

Lately, there has been a growing interest about the connectedness of people and society (Turkina et al, 2016, 2018; Li, 2018; Kali and Reyes, 2007, 2010; Jackson, 2008; Easley and Kleinberg, 2010; Albert and Barabasi, 2002; Goyal, 2012 among others). A substantial list of the key studies done in network analysis is presented in the **Appendix A.** The core of this interest, among other factors, is the idea of network – a pattern of interconnections among a set of things. In the most basic sense, a network is any collection of objects in which some pairs of these objects are connected by links (Easley and Kleinberg, 2010).

This thesis focuses, particularly, on the FDI network to investigate its role in the technological advancement of a country and argues that the relationship between FDI and the technological advancement can more accurately be understood using the network approach, as it takes both direct and indirect relationship between countries into account (Kali, 2007). Network analysis allows us to examine the structure of a relationship among countries and would provide us with a new perspective on the role of the network in different areas (Goyal, 2012; Jackson, 2008).

A network approach enhances our understanding of international relationships because it covers the whole structure of interactions among countries in addition to direct linkages. For example, statistical properties of world-trade networks are able to explain the dynamics of macro-economic variables related to globalization, growth, and financial contagion. Kali and Reyes (2007 and 2010) claim that a country's position in the international trade network is associated with that country's growth and the risks of financial crisis.

There could be different forms of relationships and connections as links, and it is easy to find networks in many domains. For example, we are part of a social network by living in a society and by connecting with neighbors, friends, colleagues, and others. This network aspect of our society is facilitated due to technological advances such as travel, communications, etc. The information we use in our everyday life also comes to us through different networks.

Understanding any one piece of information from the environment depends on understanding the way it is accepted by others and how it refers to other information within a large network of links. In this way, our technological and economic systems have also become dependent on networks (Easley and Kleinberg, 2010). Examples include networks of suppliers in the manufacturing industry, networks of users of different websites, networks of advertisers in media companies, networks of employers, and networks of jobseekers.

Kali and Reyes (2007) use the network approach to analyze the trade network to understand the architecture of globalization. By using degree centrality to measure the importance of a country's position in the network, Kali and Reyes (2007) find that the trade network is more decentralized at the low level but more centralized at the high level of trade and has a core-periphery structure. Their analysis suggests that a country's position in the network has substantial importance in the development outcome. In their analysis, Kali and Reyes (2007) consider the magnitude of connectivity, not only the exact values. This research follows a similar approach to model the global FDI network.

Later, in 2010, Kali and Reyes analyze the trade network in the context of financial crises and find that countries in the central position are affected more by a financial crisis, but that such effects are moderated if the country is better connected in the trade network. The pattern of interconnectivity among countries may explain the different extent of transmission and the amplification of the crisis. This finding justifies the argument of this thesis about technological advancement through the FDI network. Similarly, Coe and Helpman (1995) study the effects of both domestic R&D capital and foreign R&D capital on a country's total factor productivity and find that the foreign R&D has a beneficial effect on domestic productivity. However, Coe and Helpman (1995) consider that only direct bilateral trade is associated with technology spillover but not that indirect linkages can also play a major role. Thus, a network analysis is well suited to measure such indirect-linkage effects.

Earlier studies suggest that a transfer of knowledge may be facilitated by firms' embeddedness in networks and spatial proximity to network partners (Firtsch and Kauffeld-Monz, 2010; Kali, 2010). Though network studies capture indirect relationships, innovation networks, unlike clusters, are based on direct relationships, and the exchange processes within networks are critically affected by the very nature of knowledge and information. Fritsch and Kauffeld-Monz (2010) analyze 16 German innovation networks and find that strong ties are more beneficial for the exchange of knowledge and information than weak ties.

On the other hand, by discussing the effects of social structures on issues such as information about job offerings and new technologies, Granovetter (1983) points out that new information is mainly obtained from connections to actors who are not members of a closely connected part of the network rather than from the close connections. However, the overall effect of network embeddedness might be different because Granovetter (1983) does not put much emphasis on the generation of knowledge that is taking place in the core of innovation activity and related benefits. There could be a sufficient level of capabilities and incentives in the core to develop knowledge.

Networks and connectedness to outside knowledge sources provide benefits in terms of accessing and exploiting external knowledge to improve local innovation systems (Cockburn and Henderson, 1998; Powell et al., 1996; Mowery and Oxley, 1995; Kostopoulos et al., 2011). Ferragina and Mazzotta (2014) analyze the indirect benefits of foreign firms on the host country by studying the linkages between foreign firms and local firms in Italy, and they sort firms in different industries according to high-low technology level in order to better understand the effect of firms' capacity to cope with the presence of foreign firms. Ferragina and Mazzotta (2014) find positive and significant intra-sectoral spillover in the group of firms with a low technology gap. The existence of positive spillover when the technology gap is low suggests that local firms that are more productive are also more capable of acquiring benefit from the linkages.

A firm that maintains connections to the larger research community will enjoy superior access to the knowledge (Fabrizio, 2009) that will enhance that firms' innovation capability and improve the innovation system of that region. Moreover, knowledge-based growth is a product of dynamic interplay between local and non-local forces (Bathelt and Cohendet, 2014; Fu, 2008). Firms' involvement in innovation collaborations with various outside parties enriches their knowledge base and develops a better ability to assimilate and exploit external knowledge (Kostopoulos et al., 2011). Thus, networks are an important instrument for competitiveness and add value under some, if not all, circumstances, and better access to useful knowledge in the search for new innovations leads to better outcomes and helps to avoid areas of less valuable outcomes (Fabrizio, 2009).

However, to improve innovation performance, firms need to have internal capabilities to learn and improve, which can be complemented by intensity and proximity of networking (Lau and Lo, 2015). Whether a region has an innovation system or what is the nature of that system can be determined by analyzing the networking and learning capacity of the firms in that region (Cooke, 2001). The process of learning, knowledge creation and diffusion, and innovation are localized in different regions and clusters and are facilitated by the proximity of actors (Bathelt and Cohendet, 2014).

Business and social networks can also be considered important ways to overcome informal trade barriers as there are both formal and informal trade barriers in international business (Rauch, 2001). Rauch (2001) finds that the role of intermediaries in the network is important as they connect foreign agents to the domestic network, and such networks facilitate technology transfer. Nonetheless, Rauch (2001) is cautious in drawing a conclusion from his finding as networks can either improve or hinder efficiencies in international trade and suggests that an empirical study can clarify the actual scenario.

Researchers discuss the use of network analysis in different areas of international exchanges and find different implications of this approach. Recently, Turkina et al. (2016), by examining clusters in the aerospace industry, suggest that the network effect is not always limited to a particular industry or geography, and state that it is important to distinguish between different types of linkages because the structure may vary depending on the relationship. Moreover, geographical proximity alone does not guarantee the benefit of positive cluster externalities (Turkina and Van Assche, 2018; Li, 2018).

The existing literature on FDI indicates that FDI has network features. This thesis presents an overview of the literature below. FDI is not uniformly distributed world-wide – FDI, usually, tends to flow where the environment is most convenient and brings new technological knowledge. Based on these findings in the literature, this thesis formulates hypotheses about the presence of network structure in FDI distribution and the relationship between network position and technology status of a country.

2.3 Network features in foreign direct investment

It is evident from the FDI literature reviewed in the overview section that characteristics of a particular location have substantial importance in MNEs' internationalization decisions. Ownership advantages and internalization advantages are specific to MNEs, but the location advantages are the same for all the MNEs coming to a particular location. MNEs establish in distant environments in search of the most feasible option so as to reduce cost and supply the product to customers within the shortest possible time (Lall and Narula, 2004). When a major player of a certain industry outsources its operation, it allows the relative R&D to take place closer to the location of production and contributes to the improvement of the local capabilities and innovation systems.

Such connections among firms in different locations are termed as "global pipelines" to transfer knowledge in earlier studies (Owen-Smith and Powell, 2002; Bathelt et al., 2004). Bathelt et al. (2004) discuss the spatial clustering of economic activity and argue that the interaction among different actors possessing different types of knowledge is important for innovation and knowledge creation. Global pipelines bring firms from different parts of the world which are embedded in different environments. Once the pipelines have successfully been established and work effectively, they provide substantial advantages to local actors (Bathelt et al., 2004). In addition, knowledge intensive firms can grow and develop innovative projects based on the dynamics of an environment (Cohendet & Simon, 2008). Pissano and Shih (2009) describe such specific knowledge as "industrial common" and say that R&D know-how, advanced process development and engineering skills, and manufacturing competencies related to a specific technology can explain why firms in a particular industry tend to cluster in a particular location.

MNEs are credited with producing and controlling most technological advancement (Dunning, 1988, 2001; Fu, 2008). Policymakers, well aware of the direct and indirect benefits of FDI, often approach MNEs with financial incentives to encourage the establishment of local production facilities (Lall and Narula, 2004; Gorg and Greenaway, 2004). By encouraging foreign investors to invest, developing countries hope to catalyze technology transfer to local firms since FDI is associated with the existence of intangible assets of the foreign investors (Kokko, 1992, 1994; Blomstrom and Kokko, 1999). However, liberalization of the economy is not the only important thing that MNEs look for (Ritchie, 2002). The host firms need to have a minimum technical knowledge and a capable workforce to demonstrate their efficiency and attract FDI (Borensztein et al., 1998; Baranson, 1970;).

Whether an MNE will chose a location to invest depends on the economic activities going on that location. For example, Porter (1990) in his “diamond of national competitiveness”, mentions four attributes: factor conditions; firm strategy, structure, and rivalry; related and supporting industries; and demand conditions that explain the international success of a nation. Among these attributes, related and supporting industries refer to local characteristics in terms of ongoing activities of competitors and collaborators - a necessary condition to form the cluster.

Later, Porter (2000) defines clusters as a geographic concentration of interconnected companies, suppliers, service providers, educational institutions, standard providing agencies, and different trade associations. Porter (2000) mentions as well that productivity and productivity growth are higher in the firms located in clusters than in isolated ones because clusters lower the barriers to new business formation. In the cluster theory, Porter (2000) makes the competitive advantages of a location much clearer and emphasizes that clusters act like magnets to attract FDI to a country, which affirms that the presence of foreign firms in a location attracts other firms and creates cluster externalities that contribute to local prosperity. According to Porter, a location's best chance to attract FDI lies in existing or emerging clusters.

Studies have more often linked FDI with the long-term economic development of a country (Keller, 2010; Ritchie, 2002; Lall and Narula, 2004; Borensztein, 1998; Grossman and Helpman, 1993; Gorg and Greenaway, 2004). Similarly, FDI can be considered a channel to promote cluster formation. Depending on the location advantages, clusters can form in a country, in a region, or even in a city. Such geographical concentration of industries amplifies productivity, innovation, and transactions while it reduces transaction costs (Porter, 2000). Policymakers would usually be more responsive to the specialized needs of clusters that enhance their growth beyond the traditional industries (Porter, 2000; Lall and Narula, 2004). Not surprisingly, investors would always consider such places the most convenient in which to make investments.

When an MNE establishes production and R&D facilities in a location, it gets into business and establishes linkages with other local firms. Such intra- industry and inter-industry linkages stimulate knowledge transfer among firms, though the extent may differ in horizontal and vertical linkages. Thompson (2002) studies the role of FDI clusters in technology transfer by separating horizontal and vertical linkages. The findings suggest that though the clustered MNEs attract more suppliers than the dispersed MNEs through vertical linkages, technology and knowledge spillover are better facilitated through horizontal linkages. De Propris and Driffield (2006) also suggest that firms in a cluster benefit more from the FDI than those are out of the cluster. Moreover, the benefit is greater when firms from a knowledge intensive cluster connect to foreign knowledge hotspots (Turkina and Van Assche, 2018; Bathelt, 2001).

Though most of the researches related to FDI are done using firm and industry level information and suggest asymmetrical flow of FDI, we observe similar pattern in the country level. It is apparent in the literature that the distribution of FDI is quite unequal across countries. Casi and Resmini (2014) find that here are several countries or even regions within a country that attract relatively more FDI than others. Accordingly, some regions attract FDI of specific nature such as R&D and knowledge intensive FDI (Turkina and Van Assche, 2018) because FDI affiliates put emphasis on local capabilities (Bathelt and Li, 2013; Lall and Narula, 2004). These circumstances indicate that characteristics of a location are of significantly related to the distribution of FDI. There are some core countries that warrant more attention from foreign investors than other peripheral countries do. However, these studies, so far, have been only conceptual.

Thus, to deepen the understanding of FDI distribution and provide with empirical evidence from a network approach, this research proposes the following hypothesis:

Hypothesis 1A: Foreign Direct Investment network is hierarchical and has a core-periphery structure.

2.4 Network features in innovation systems and technological advancement

Technology plays a major role in the development of a country's economy because the most economically developed countries are also the most technologically developed (Keller, 2010; Cooke, 2001; Hermes and Lensink, 2003). Enos (1989) points out that there are some countries in the world that originate technology, some that receive, and some that do both simultaneously. Since FDI is a major channel of technology transfer, this research argues that the countries that receive more FDI are also more technologically advanced.

Recently Ferrier et al. (2016) apply the network approach to understand the relationship between trade network and international technology transfer. Ferrier et al. (2016) find evidence that connectivity in the trade network plays a significant role in technology transfer – better-connected countries tend to perform better by quickly adopting the latest technology to replace obsolete ones. FDI contributes to the improvement of the technological advancement of the host region in four ways: firstly, R&D, R&D labs, and other forms of innovation generated by foreign firms increase the innovation outputs in the region directly; secondly, spillovers emanated from foreign innovation activities – linkages between foreign and local firms – may affect the innovation performance in the region they locate; thirdly, FDI may affect regional innovation capacity through competition effect; finally, FDI may contribute to regional innovation capabilities by advanced practices and experiences in innovation management and thereby greater efficiency in innovation (Fu, 2008).

Technology originates predominantly in developed countries and generates most of the world's income, and one common notion that separates developed countries from developing countries is that developed countries have advanced technology while the developing countries lack it (Enos, 1989). Literature suggests that technology can be regarded as patentable blueprints, plans, mechanisms, formulae, and the like. Consequently, the transfer of technologies may not be limited to formal processes alone, but well-managed linkages are needed for efficient transfer of technology.

When a newly developed technology is available through trade to at least one other country in addition to the country of the original inventor, the recipient internalizes the technology which becomes a part of the knowledge of the recipient country, and so the cycle continues (Lumenga-Neso et al., 2005). Thus, technology transfer is not confined to the direct trading partners of the innovator (Ferrier et. al., 2016). Once the knowledge is exposed to a partner of the innovator, that partner may expose the newly obtained knowledge to other partners that are not directly related to the innovator – the spillover effect continues beyond the initial exchanges. The indirect relationship allows countries to access a new technology without having any direct linkage with the innovator country.

In this process, the first transmission only happens through direct linkages. The subsequent transfer generally happens through indirect linkages with the innovating country. In an effort to distinguish between produced R&D and available R&D, Ferrier et. al. (2016) define produced R&D as the knowledge that resides within the country of the original inventor, but which can be transmitted to other countries through trade. Once the technological knowledge is available to the other country, it becomes available knowledge for that country, and that available knowledge can later be transferred to other countries.

Thus, indirect linkages are at least as important as direct linkages in transfer of technology. Similarly, Albert and Barabasi (2002) provide empirical results of the use of the network in different areas and note that indirect linkages play a role in spreading ideas.

These network features are noticeable in transfer of technologies. At the inception of a new technology, it is adopted by a small set of countries for different reasons – the new technology is costly and out of reach for other countries or those countries are not yet sure of the success of that new technology. Though technology is transferred through networks, the process can also be blocked because of network structures. In a densely connected network, individuals have many linkages among themselves and are resistant to other outside forces (Easley and Kleinberg, 2010; Rogers, 2000). To adopt a technology, interaction and understandings with other participants are important.

Most of the literature on technology transfer focus on concrete methods of technology transfer such as sale of technology, licensing, and transfer to subsidiaries. MNEs move technology between subsidiaries and divisions through equipment, personnel, and formulas among other things. The best outcome from the convergence of local and foreign firms depends on the emitting capacity of the source firms and the receiving capacity of the subsidiaries and divisions (Amesse & Cohendet, 2001; Volberda et al., 2010). Amesse and Cohendet (2001) show in their model that though firms hold significant pieces of knowledge, they need to engage in a network relationship which offers precisely a way to share and exchange knowledge complementarities with other firms. By doing so, firms can access complementary knowledge held by other firms to use that knowledge more efficiently (Cohendet et al., 1999; Bathelt et al., 2004).

Sometimes a technology may not be adopted by people easily, regardless of its advanced features. Rogers (2000), in his book on diffusion of innovations, points out a number of factors to explain why an innovation can fail to spread in a particular environment. According to Rogers (2000), the success of an innovation depends on how complex it is for other people to understand and implement; its observability, so that people can become aware that other people are using it; its trialability, so that people can mitigate its risk by adopting it gradually and incrementally; and above all, its overall compatibility with relevant social systems. The last point is quite important because new innovations generally come from outside, and it is hard for an innovation coming from outside to be recognized in a closely connected network in which the behavior of one affects the behavior of many others.

There are two distinct benefits of adopting the behavior of others in a network: informational effects, implying that the choices made by others can provide indirect information about what they know; and direct-benefit effects, implying that there are direct benefits in copying the decisions of others – for example, the payoffs that arise from using a compatible technology instead of an incompatible one (Easley and Kleinberg, 2010). Because of these factors, new ideas, behaviors, practices, and technologies disseminate through a social network, as people motivate their friends to adopt new ideas.

In network studies, diffusion of ideas is often referred to as social contagion (Easley and Kleinberg, 2010). Ideas can spread from person to person across a network that connects people, and people have the liberty to make decisions to adopt a new idea or innovation. Given that participants can make strategic decisions in a social network, network analysis can provide us with the answer as to why networks take specific forms.

In case of the diffusion of information, participants' payoff will depend on the access to the information flowing in the network (Jackson, 2008). These conditions will motivate participants to connect to the network and will eventually affect the network structure.

In a network, however, it is possible that there will be a set of early adopters, and their adoption of a new technology will eventually spread that technology throughout the network. This circumstance has implications for strategic decision making (Easley and Kleinberg, 2010) – the participants on the periphery of the network can decide to connect with high status participants that will make their connections in the network richer and will eventually improve their status in the network. When individuals have incentives to adopt the behavior of their neighbors in a network, a new behavior starts with a small set of adopters and gradually spreads outwards through the network (Easley and Kleinberg, 2010). Though such effort involves some costs, the benefits generally outweigh the costs.

Thereby, in all these settings, the network structure encodes a lot of information about the pattern of the relevant connections because the magnitude of success of the participants is affected by their positions in the network. "having a powerful position, however, depends not just on having many connections providing different options, but also on more subtle features – such as the power of other individuals to which one is connected" (Easley and Kleinberg, 2010). For instance, by exploring the effect of inter-cluster networks, Turkina and Van Assche (2018), by exploring the effect on cluster innovationinter-cluster, find that linkages with advanced clusters has important implication for local innovation system. Similarly, countries that are better connected in the network tend to perform better by quickly adopting the latest technology (Ferrier et al., 2016), and core countries enjoy privileges over the peripheral countries in a network (Benito et al., 2003).

Above all, the frequency of technological advancement is increasing with the passage of time, and this ongoing process forces businesses to remain flexible and adapt their business activities to the latest technologies available. Such collective adaptation of newest technologies by businesses in a location or in an industry is believed to improve the technological knowledge of that location or industry. The research summarizes the discussion above in the form of the following hypothesis.

Hypothesis 1B: Core countries in the FDI network have a relatively higher technology level than peripheral countries.

2.5 Technological advancement and foreign direct investment

The literature on technology transfer and technological advancement is extensive and varies according to perspective and discipline which can be as varied as political science, economics, sociology, public policy, marketing, and management of technology (Kumar et al., 1999). Technology, technology transfer, and technological advancement have been of research interest to scholars for a long time and have been studied from different perspectives. One such perspective leads towards the study of the relationship among technology transfer, technology absorption, and economic growth, while others focus on different channels of technology transfer (Eaton and Kortum, 2001). A better understanding of cross-country technology transfer through FDI network would provide insight into the role of FDI in economic and technological advancement of a country. Some key studies done on technology transfer and technological advancement are presented in **Appendix B.**

2.5.1 Channels of technology transfer

Scholars recognize various modes and channels of technology transfer, but quantifying technology transfer remains yet to be resolved. There is no single way to measure technology transfer. According to Radosevic (1999), there are three main problems in the quantification of technology flows. First, technology itself is not easily identifiable. Statistics monitor the most explicit forms of technology effects such as R&D, patents and licenses. There is still a large stock of technological knowledge embodied in enterprises and in their networks, which is not measurable. Second, technology flows through different channels and takes different forms, this diversity makes comparison of technology flows along different channels difficult if not impossible. Third, separating technology from transactional elements and costs is difficult.

Baranson (1970) defines technology transfer as transfer of specific knowledge that enables the recipient firms to produce a particular product or service. However, technology transfer is not only about the transfers technical product or service specific know-how but also about the transfer of required capacity to master, develop, and produce that underlying technology autonomously if needed. Farhang (1997) points out that transfer of technology in the manufacturing sector requires not only the transfer of technological knowledge in the form of process sheets, blueprints, products, and material specifications but also the transfer of the know-how of higher-level engineering and technical personnel.

Technology can be transferred in many different ways: through formal market transactions or through informal non-market transactions that can further be voluntary or involuntary (Blomstrom and Kokko, 1999). Researchers mention that though it is possible for developed countries to gain access to advanced technology by cross-licensing, developing countries are not in a position to acquire knowledge in that way (Keller, 2004; Baranson, 1970). This situation allows FDIs coming from technology-developed countries to play a major role in diffusing technology.

However, all technologies cannot be codified and transferred at a minimal cost, and we know very little about the transfer of technology. Technology and technology transfer concepts encompass different interpretations and views depending on the organizations' objectives, research domains, underlying theories, and applications among other things.

Technology in embodied form can be transferred by using foreign intermediate products in final output productions. However, the distribution of technological knowledge across countries is not equal. The original inventors may not want to distribute the technology for free. At the beginning, inventors will preclude others from using the technology by patenting. Later, they may sell the technology to others, but using advanced technology requires investment - in terms of required skill and facilities to operate the technology – from the users. According to Keller (2004), international economic activities such as trade, FDI, etc. stimulate international technology transfer and raise the probability of international R&D spillover. Keller (2004) mentions that international technology transfer is becoming more important with the rising level of global economic integration.

Different aspects of technology transfer include vertical and horizontal, formal and informal, active and passive role of foreigners, embodied and disembodied, degree of packaging, direct and indirect, intra-firm, sales and intermediate forms, etc. (Radosevic, 1999). In his study, Radosevic (1999) sorts out different types of technology transfer mechanisms – FDI, joint ventures, licensing, import of goods, co-operative alliances, subcontracting, export, transfer by people, and development assistance.

Thus, international trade is a major channel for technology transfer, and technical knowledge is gradually becoming an important item in international trade with the rising cost of innovation and demand for advanced technology across the world (Keller, 2004; Grossman and Helpman, 1993). As a result, technology can change the trend of international trade. Grossman and Helpman (1993) suggest that the change can happen in both directions – on one hand, technology can affect the trade pattern, and on the other hand, international trade and FDI can affect the technology by acting as a mode of transfer.

FDI is an important instrument for distributing resources in the world economy and can lead to a wider dissemination of technology internationally because of MNEs' dominating position in the creation of new technology (Baranson, 1970). Lall and Narula (2004) point out that FDI transfers technology to local firms in four ways: backward linkages, labor turnover, forward linkages, and international technology spillovers. According to Kokko (1992), there are four means of international technology transfer depending on whether the transfer is formal or informal and active or passive: joint venture/licensing, goods trade, linkages, and trade journals/scientific exchanges. Crespo and Fontoura (2007) also mention five main channels of technology transfer: demonstration/imitation, labor mobility, export, competition, and backward and forward linkages.

While strategic decisions play a role in deciding the quality of technology transferred, the capabilities of recipient firms are also important. Saggi (2002), focuses on three potential channels of technology spillover - demonstration, labor turnover, and vertical linkages and finds evidence for the positive relationship between FDI and economic growth. The quickly foreign firms establish linkages with local firms, the rapid will be the process of technology transfer and technological advancement as a result of local firms' exposure to and the familiarity with the new technology (Gorg and Greenaway, 2004).

Though the boundary between FDI and co-operative alliances is difficult to define, co-operative alliances are suggested to be a part of spreading of network relationships among enterprises (Radosevic, 1999). However, there are disagreements among analysts about whether alliances assume the role of two-way technology transfer. Subcontracting as a technology transfer mechanism depends on the sourcing decision of a firm. This mechanism is unevenly spread along the value chain because the firm may choose to purchase goods of their own design and specification or to purchase goods produced as per the producers' design (ibid).

Thus, modes of technology transfer range from non-equity entry modes such as export and contractual agreements to equity entry modes such as joint ventures and FDI. FDI is preferred to licensing when the technology is complex and foreign affiliates lack the sophistication to handle the technology (Baranson, 1970). Technology can be embodied in both imported and exported goods. Among imported goods, capital goods are considered to have highest technological content (Radosevic, 1999). So, mastery of capital goods technologies is essential for long- term growth. Foreign markets are also sources of learning because the quality of products and services exported is decided by the communication between buyer and seller (ibid). To ensure the quality of products and services, buyers usually transfer the required knowledge to the producers.

However, the type and extent of technology transfer also vary with the characteristics of technology, for example, complexity of a knowledge. The more complex and latest the technology, the less willing MNEs will be to transfer the technology to third parties (Baranson, 1970; Sinani and Meyer, 2004). Capabilities of host countries such as labor skills, competitiveness, etc. also determine the extent of technological advancement

(Teece, 1977). Technology spillover occurs when activities of one firm lead to improvements in the technology and production of other firms, such that the first firm cannot capture all the benefits created by its technology (Sinani and Meyers, 2004). Such spillover can happen in two ways: through backward linkages where local firms supply intermediate products to be used by the foreign firms, or when local firms purchase intermediate products produced by the foreign firms (Liu, 2008). According to Liu (2008), technology spillovers are more likely to occur in firms within an industry because the firms produce the same type of products. Technology and management knowledge used by foreign firms can be easily applied to local firms in the same industry. However, spillover can also occur across firms in different industries. For example, when firms from a different industry become clients or suppliers of firms in a different industry, all the firms need to exchange some knowledge to meet their expectations.

According to Sinani and Meyers (2004), there are four main channels through which spillover of technology materializes – demonstration and imitation, training of local employees, competition, and backward-forward linkages. Technology spillover occurs when foreign firms invest in a country and demonstrate new products and technology to the local firms, which may eventually master the technology and imitate in their production processes. Foreign firms also train local employees to use new technology to maintain the quality of product and service in backward-forward linkages (ibid). However, competition might have a negative effect on local firms' productivity in the short-run when foreign investment reduces domestic productivity by forcing local firms to cut production (Aitken and Harrison, 1999; Jordaan, 2012).

To conclude, the literature reviewed in this section suggests that not all countries can afford to invest in advancing technological innovation. Other countries depend on the transfer of such innovation from developed countries, and there are several ways to transfer technology. International technology transfer can occur through both market transactions and externalities (Keller, 2010). Thus, technology can be transferred both directly and indirectly, especially - through spillover, which is the focus of this thesis.

2.5.2 The global FDI network and technological advancement

The a priori knowledge of how the presence of foreign firms affects host country firms is convoluted and leaves much room for different interpretations depending on the circumstances. Foreign firms can either intensify competition in the market to increase their market share and force local companies out of the market (Aitken and Harrison, 1999) or alternatively aid local firms to improve their capacity through knowledge and pecuniary spillover (Blomstrom and Kokko, 1999).

From the definition and scholarly articles on FDI reviewed in earlier sections, it is clear that foreign investors make such investments because they want to protect their specialized knowledge and latest technologies as long as possible. The original inventor of a technology may patent the innovation so as to exclude others from using the technology for a certain period of time (Keller, 2004). Not willing to share the newly-developed technology with others, MNEs choose to set up their own facility and internalize the activities (Dunning, 1998, 2001). In this way, investors can retain full management control and lower the risk of technology leakage.

Despite this, the literature on technological advancement suggests that international transfer of technology is strongly connected to FDI (Helpman, 1997; Baranson, 1990; Lall and Narula, 2004; Kokko, 1992). MNEs play a major role in the transfer of technology by exposing local firms to new technologies. On one hand, MNEs need to share some of the technology or at least the specialized skills to enable the local workers to use that technology so as to get the maximum return. On the other hand, because of the public-goods characteristics of technology, MNEs cannot really exclude others from eventually getting access to the latest technology (Saggi, 2002). Aitken and Harrison (1999) even find the share of foreign equity is particularly high in scientific equipment. The trend is still the same, in fact stronger. In 2017, among the industries that drew FDI, more than half were in technology industries (UNCTAD).

Consequently, FDI as a channel of technology transfer has interested researchers, who often make a distinction between inward foreign direct investment and outward foreign direct investment (Xu and Wang, 2000). A substantial part of the literature suggests the important role of FDI in technological change and economic development. This section of the literature review focuses on FDI as a mode of technology transfer and technological advancement.

Though the global flow of FDI fell by 2% in 2016, the weight of tech MNEs in international production has increased dramatically from 2010 to 2015. The number of tech MNEs in UNCTAD's ranking more than doubled during this time period. The World Investment Report 2017 by UNCTAD reveals that more than half of the FDI in developed countries is focused on IT and professional services. This result is consistent with that of the previous years. In addition, information and communication - which includes telecommunications, data processing, software programming – is emerging as an attractive industry in selected regions. This notion confirms the growing importance of the digital economy beyond the developed countries.

Technology is fundamentally changing the way firms produce and market products and services across borders. With the help of technology, firms can communicate with and sell to overseas customers without much physical presence in the foreign markets. Still, MNE’s go to other countries, and have different reasons for doing so. MNEs usually go to developing countries to reduce production costs and developed countries to access advanced knowledge. In the case of developing countries, MNEs need to assist the host firms in capacity building by transferring technologies and giving advice. In developing countries, firms in more technology-intensive industries show a higher propensity to adopt digital technologies.

By studying the technology spillover in the UK and the USA, Keller (2004, 2010) finds evidence for FDI spillover. In some cases, the evidence of spillover through FDI is stronger than through import (Keller, 2010). Similarly, Nakandala (2008) also finds that in addition to direct benefits, FDI has indirect long-term benefits such as technological advancement in the host country. Liu and Wang (2003) note that FDI is a gateway to advanced technology for host countries. Though physical capital and labor account for the major part of the industrial production, the outcome of a foreign presence is more than just physical capital (Liu and Wang, 2003; Gorg and Greenaway, 2004). De La Potterie and Lichtenberg (2001) also find evidence that FDI transfers technology across borders.

Though it is possible to access the latest technology in exchange for a price, new technology generally requires demonstration in the context of the local environment before the technology can be transferred (Findlay, 1978). This is where MNEs come forward with new technology. Besides supplying the much-needed capital to promote technology upgrades in local firms, MNEs also demonstrate new technologies to local firms by arranging various training programs and exhibiting new products (Findlay, 1978; Narula and Marin, 2003; Sinani and Meyers, 2004; Aitken and Harrison, 1999; Jordaan, 2012).

The more chance the local firms have to observe the advanced technology used by the foreign firms, the faster domestic technology grows. Accordingly, FDI benefits a host country by enhancing the overall level of technology and by fostering economic growth. Besides bringing in capital and creating employment opportunities, FDI activities lead to technological advancement of local firms (Caves, 1996). Nonetheless, MNEs can sometimes suppress and distort the development process if the local firms are not ready for the changes.

Djulius (2017) explores the relationship between FDI in a country and the productivity of local companies in export-oriented industries of that country. By studying the Indonesian manufacturing industry, the author notes that export-oriented local companies were able to employ workers who had experience of working in foreign companies. To meet the demands and standards of foreign companies, local companies need employees who have already worked in the foreign companies and absorbed knowledge of products and process standards.

Labor turnover is also possible among different industries in a region. In this case, the knowledge may not always be related to a product or process but may be related to managerial skills. Another important finding in Djulius's (2017) study is the importance of competition in knowledge spillover. Because of export orientation, local companies can hire employees who formerly worked in the foreign companies and pay the same salary they were receiving in the foreign companies.

In the case of FDI, the conditions are different. Foreign companies are usually more capital intensive than local companies, and they directly or indirectly assist local companies to produce products to meet their standards by providing various supports. According to (Djulius, 2017), because of the difference in capital intensity of local and foreign firms, transfer of knowledge happens either through technical assistance or through product specification. A high level of industry specialization may occur because of agglomeration in certain regions. Through agglomeration, companies in that region can easily access related knowledge and other developments in the industry. It is also easier to get a better supply of skilled workforce because agglomeration allows workers to join companies and contributes to exchanging their knowledge and experiences (Pisano and Shih, 2009).

Foreign firms can be seen as source of new knowledge and technologies to local supplier firms since they offer various training programs, technical assistance with the production process and quality control, and other aspects. Because of such exchanges, local firms can access advanced technologies. Foreign firms offer several types of support more frequently. For instance, they usually offer more support under the sort of technology gaps that affect the production process of the supplier firms (Jordaan, 2012). Thus, a local supplier benefits more, in terms of technological assistance, from a large technological gap. Foreign firms reveal new pieces of technology to local firms, and local firms can absorb new technology simply through exposure or through labor turnover.

When the employees of foreign firms move to work in local firms, they bring embedded knowledge gained through experience. Local firms can also access new technology more directly through business linkages as buyers or suppliers of foreign firms.

The technological gap between firms need to be sufficiently large for significant changes to occur. A large technology gap signifies sufficient scope for the local or lagging firms to learn and upgrade, which suggests a positive relationship between technology gap and technology spillover. Applying this notion of FDI spillover, it is possible to say that a large technology gap may act as a catalyst to technology spillover, rather than a hindrance (Findlay, 1978; Blomstrom and Kokko, 1999). Accounting for this notion, local firms can try to improve their absorptive capacities when there are sufficient technology gaps and scopes.

Sometimes, the result of spillover differs between and within industries. An inventor firm or an owner firm that has the latest technology will, surely, have enough incentive to protect the technology as long as possible to obtain maximum benefit. However, they might be willing to exchange the technology with firms in different industries. There is no clear evidence of why and how spillover effects occur.

Foreign firms may also force local firms to improve their technology and production processes to remain on the cutting edge of technology (Aitken and Harrison, 1999). In that case, the foreign firms are not seen as the source of new technology but seen as competitors. The result of such dominance in the industry can be both positive and negative depending on the strength of the local firms. Nonetheless, the important point to note is that though foreign firms provide technical assistance to local firms for their own benefit, foreign firms cannot completely recover what they give away. Local firms can use the knowledge gained from one client firm to serve their other client firms in the same industry. On the other hand, productivity in domestically owned firms may decline with an increase in FDI because the presence of foreign firms in the market exposes the local firms to higher competition! Foreign firms producing for the local market may draw demand away from domestic firms, resulting production cuts in local firms (Aitken and Harrison, 1999).

Some firm-specific knowledge of foreign firms may traverse to local firms when local firms are exposed to products or production processes, marketing techniques, or receive assistance from upstream and downstream foreign firms. To support this understanding, Liu (2008) finds that FDI facilitates technological advancement of domestic firms through spillover. The effect of spillover sometimes decreases the productivity level of domestic firms in the short run but increases it in the long run. Thus, the overall advantages of FDI associated with productivity and technology gain are positive.

MNEs as agents of FDI not only transfer the “hard” – patentable form of technologies but also create positive externalities by transferring “soft” technologies such as marketing and managerial skills (Thompson, 2002). Thompson (2002) studies Hong Kong garment firms with manufacturing investments in mainland China to understand whether FDI within geographical clusters transfers technology more than that which is geographically dispersed. His research findings suggest that the clustered FDI is better at transferring technology than the dispersed FDI.

Even though a large number of scholars find evidence of technology spillover through FDI and its role in development, we know little about the process of technological change in foreign subsidiaries and the consequent spillover effect of FDI (Frost, 2001). When MNEs go to a host country, technological advancement can happen in two ways (Keller, 2004). On one hand, the subsidiary firm can bring along technology from the home country and disseminate it in the host country as inward technology transfer. On the other hand, MNEs can also internalize technology from the host country as outward FDI technology sourcing (Keller, 2004). In support of this idea, Xu and Wang (2000), find evidence of the significant role of outward foreign direct investment in technological advancement but no evidence for inward foreign direct investment

Nonetheless, FDI is considered one of the major channels of technology transfer because FDI makes available the technology embodied in foreign knowledge that would otherwise have been costly and unavailable (Helpman, 1997; Hermes and Lensink, 2003). In FDI, the control of using transferred resources remains with the home-country company, giving it the strategic decision-making power – how much, when, and to whom to transfer technology (Radosevic, 1999; Zhao, 2006). Countries most often rely on successful assimilation of foreign technology to develop local technology, but MNCs often transfer older technologies to subsidiaries and other partners to maintain the upper hand in future competitions (Saggi, 2002). Furthermore, MNCs transfer technology to the most competent local firm to minimize cost and to maximize returns. Because of technology organization activities of MNEs', Dunning (1998, 2001) suggests MNCs as network mobilizers. This suggestion implies that the better integrated a country is in the FDI network, the better is that country's technology status.

Moreover, interorganizational networks can be rewarding for firms to gain access to knowledge, to facilitate learning process, and to foster knowledge creation (Volberda et al.,2010). Dhanaraj et al. (2004) also identify the importance of social embeddedness in transferring tacit and explicit knowledge. Broad networks can enhance the capability to recognize and assimilate complex ideas, and Uzzi (1999) finds that it is easier to transfer tacit knowledge through strong ties.

One important point to note at this point is that technology transfer may happen in both ways – by inward FDI or outward FDI (Keller, 2004; Xu and Wang, 2000), suggesting that there could be a cyclical relationship between FDI and the local knowledge capabilities of a country. For instance, on one hand, the pre-existing knowledge and capacity of a certain location determine the relative strength of that place to attract FDI (Porter, 2000), and on the other hand, FDI performs as a gateway for the domestic firms in that location to access advanced technology and improve their own knowledge (Liu & Wang, 2003).

Thus, it is possible that the embeddedness of a country in the global FDI network allows the country to improve its technology status, but it is also possible that the improvement in a country's technology status allows the country's firms to conduct more FDI activities to other knowledge hotspots or large markets. The circumstance implies the existence of endogeneity in the relationship between FDI and technological advancement. However, regardless of the directions of knowledge flows, it is evident that a country's FDI activities and its process of technological advancement are closely associated.

It is obvious from the existing literature that the development of technological capacities is the outcome of a complex interaction among different actors in the innovation systems (Fu, 2008). In addition, technological capability is largely related to the external knowledge available to the firm and the integration of external and internal knowledge (Teece et al., 1997). Thus, a social network analysis can be a useful measure to assess the intensity of linkages among different actors and the process of knowledge creation (Simon, 2009). Network analysis provides us with information such as the position and power of individual or a group of countries in a particular region or in the whole network (Goyal, 2012; Jackson, 2008).

Similarly, in international business, regional integration can significantly affect the scope and competence level of firms (Benito et al., 2003). Benito et al. (2003) study Denmark, Finland, and Norway to understand the effect of regional integration on subsidiary roles in peripheral countries, given that Denmark and Finland are part of the EU while Norway is an outsider. The findings suggest that countries that are part of the integration have more chances to attract FDI than outsiders do, and core countries enjoy privileges over the peripheral countries because subsidiaries located in the EU area were able to perform more efficiently than the subsidiaries located outside of it. Similarly, Kali and Reyes (2007) study the global trade network and find that a country's position in the network has substantial importance in the development outcome.

Based on the literature reviewed, this research proposes the following hypothesis.

Hypothesis 2A: A country's technology status improves with the improvement in its position in the FDI network.

2.6 The role of absorptive capacity in technological advancement and determinants of absorptive capacity

From the literature on technology, technology transfer, and technological advancement, we know that some countries are more technologically developed than other countries are, some countries receive more FDI than other countries do, and technology diffuses through FDI. But, we do not know whether all countries that receive FDI also have the same capacity to absorb technology from FDI. Literature suggests that FDI is positively associated with the innovation efficiency in a host region, but the strength of the positive effect of FDI depends on the availability of the absorptive capacity and the presence of innovation complementary assets in the host region (Fu, 2008; Cohen and Levinthal, 1990; Zahra and George, 2002; Kostopoulos, 2011; Mowery and Oxley, 1995; Hermes and Lensink, 2003; Bathelt and Cohendet, 2014).

This part of the literature review discusses the importance of absorptive capacity in deriving benefits from FDI and the determinants of absorptive capacity.

2.6.1 The role of absorptive capacity in technological advancement

MNEs have long been an important source of foreign technology and financial capital (Keller, 2010; Fu, 2008). With the rising costs and risks of innovation, MNEs are continuously searching for new locations to lower costs and protect technology (Lall and Narula, 2004). As explained in the earlier section, the existing literature provides substantial evidence that the foreign investors want not only to protect their specialized knowledge and technology but also to ensure the maximum return from any particular location. In order to do so, foreign investors seek factors compatible with their own motivations, which intensifies the importance of the competitive and the comparative advantages of various locations (Kokko, 1992).

Dunning (1988, 2001) emphasize location advantages mainly from the MNE's perspectives. However, location advantages are at least as important for the host firms and the host countries as for the MNEs if considered from the perspective of the development opportunities created by FDI. Globalization brings opportunities for countries with diverse knowledge to share, which creates a domino effect and enhances the local knowledge base (Kastelle et al., 2006). These stronger local capabilities attract FDI, which improves the capabilities further, and so the process continues (Porter, 2000).

The issue of firms' absorptive capacity (Cohen & Levinthal, 2000) within and across sectors has been widely studied in the literature on FDI and spillover effects (Findlay, 1978; Blomstrom and Kokko, 1999; Kokko et al. 1992, 1994; Saggi, 2002; Jordaan, 2012; Girma, 2005; Gugler and Brunner, 2007; Volberda et al.,2010 among the others). Some key studies done on the roles of absorptive capacity in technological advancement is reported in **Appendix C**. This part of the literature reviews focuses on the importance of local strength as absorptive capacity in technological advancement through FDI.

The literature suggests that technology transfer is not solely about transferring proprietary information and rights to other firms. Transferring tacit technology involves transfer of both technological information and capability to master that specific technology, and a successful transfer of technology requires various investments in learning to acquire a tacit knowledge (Baranson, 1970; Farhang, 1997; Teece, 1977). Moreover, valuable technological knowledge which is the intangible assets of the firm is never easily transferred from one firm to another because the technological learning process is needed to assimilate and internalized the transferred technology (Lin, 2003).

Nevertheless, the process of technological advancement is not straightforward. Wahab et al. (2012) suggest that both technology and technology transfer have different dimensions depending on the underlying theory and application. Strong local capabilities to attract the technology-intensive FDI are crucial in order to gain access to the internal knowledge system of the MNEs and drive the spillover benefit (Borensztein et al., 1998). FDI is an important vehicle for technological advancement, but the FDI contributes to economic growth only when a sufficient level of absorptive capability of the advanced technologies is available in the host economy (Borensztein et al., 1998; Lane et al, 2006). To elaborate the concept, Cohen and Levinthal (1989) define the absorptive capacity of firms as the ability to identify, assimilate, and exploit knowledge from the environment.

The majority of the empirical work done has pointed to the fact that the existence of knowledge spillover accelerates technological advances. However, firms must have the capacity to evaluate and use external knowledge, as Cohen and Levinthal (1990) point out. Cohen and Levinthal (1990) also emphasize that these capacities are largely a function of prior related knowledge, and such prior related knowledge is a by-product of internal R&D activities. To be specific, the extent of a firm's ability to capture external knowledge depends on that firm's earlier efforts to innovate. Thus, access to external knowledge is possible only when a firm has already generated a mass of related knowledge that permits the firm to understand the new knowledge in the environment.

Thus, reading the published or codified knowledge is not enough to utilize the results in the absence of prior related knowledge (Fabrizio, 2009; Amesse and Cohendet, 2001; Gorg and Greenaway, 2004). Amesse and Cohendet (2001) suggest a technology transfer model by considering the ranking of the firms' activities according to core-competencies and separate the model into four zones in which each zone is characterized by a given set of relationships between the firm and the external organizations considering technology transfer and other institutional design. Their result suggests that the quality of the technology transfer process is heavily dependent on the absorptive capacity of the firms. Similarly, even if the knowledge is available in the public domain, knowledge outside the boundary of the firm is not freely and effortlessly absorbed by the firm. A condition suggesting that knowledge from external sources is not equally absorbed and exploited by all firms.

Though external knowledge is crucial for innovation, such knowledge may be of tacit nature, highly context specific, and require certain capabilities in order to be absorbed (Fritsch & Kauffeld-Monz, 2010; Cohen and Levinthal, 1989; Narula and Marin, 2003). According to Enos (2008), it is believed that developing countries can grasp technology from developed countries with proper instructions, and developed countries are in the best position to instruct. This implies several things: technology can best be learned from those who are already knowledgeable, the advanced knowledge of developed countries, and the ability of developing countries to absorb knowledge.

If the technology is a complex one, it requires substantial amount of investment from the recipients to use the technology, and recipients will not get the benefit of the new technology unless they have the required absorptive capacities (Teece, 1997). The technical and managerial competence of the recipients – age/experience and size of the business, R&D activities, host country infrastructure - are important determinants to understand the extent of technology absorption (ibid). Another critical factor in transferring technology is the extent to which the technology is understood by the parties involved because the older the technology, ceteris paribus, the better understood the technology, which facilitate the transmission and absorption (ibid).

It is evident in the literature that the scope of FDI spillover is a function of local firms' ability to absorb technology (Ferragina & Mazzotta, 2014; Fabrizio, 2009). The literature on technology transfer and technological advancement frequently assumes that there is a technology gap between local and foreign firms which creates opportunities for knowledge externalities, transfer of more efficient technologies, and better managerial practices (Caves, 1996; Blomstrom and Kokko, 1999; Benito, 2003; Gorg and Greenaway, 2004). Thence comes the notion of absorptive capacity. Gauging the local characteristics and technology gap, foreign investors will decide where to invest and what kind of technology to transfer. The bigger the gap the lower the quality of technology transferred and the lower the potential for spillovers (Gorg and Greenaway, 2004).

In several studies, the existing technological gap between the firms is interpreted as the reverse of absorptive capacity; a large technological gap is equated with a low-level of absorptive capacity (Kokko, 1994; Girma, 2005). Kokko (1994) finds in Mexico that even a substantial amount of industry-wide FDI may fail to result in positive spillover when the technology gap is large. Girma (2005) studies UK manufacturing firms to measure the FDI spillover and finds that positive spillover occurs only when the technology gap between the firms is small. These findings can be interpreted as emphasizing the significance of absorptive capacity – that the spillover benefit will transpire if the local firms have a sufficient level of absorptive capacity.

However, this interpretation of the technological gap is ambiguous (Jordaan, 2012). It is possible that when local suppliers are too technologically backward to upgrade, investors may lower their technical support. Alternatively, when the technological gap can be interpreted as scope of technological improvement for both firms, foreign firms will increase their support. Now, this later interpretation signifies two important points: the local firms already have some technological abilities of their own and the foreign firms have experience in that particular type of technology.

Again, because of the firm-specific nature of technology, international technology transfer is an investment process – developers invest to preserve their technological capabilities, and recipients invest to learn those capabilities. This circumstance suggests the notion of technological distance or technology gap. Technology gap is related to the cost and magnitude of technology transfer even if the technology is a mature one and the general characteristics of that technology are publicly known (Radosevic, 1999).

Rogers (2000) defines diffusion as a process through which an innovation is communicated through certain channels over time among other members of a social system. However, all innovations are not spread at the same rate. Whether the innovation will be adopted by others or not depends on certain characteristics of the innovation itself and those of the adopters. For example, Rogers (2000) mentions past experience of potential adopters is a deciding factor in the diffusion process.

Jordan (2012) studies FDI firms in Mexico to understand whether certain characteristics of local firms capture aspects of the level of absorptive capacity are important for the spillover benefit to materialize and finds that positive intra-industry spillover occurs only in high-tech industries. The findings indicate that local supplier firms of FDI firms benefit from positive FDI spillover. FDI firms are engaged in different types of knowledge transfer activities of both technological and organizational nature. When foreign firms have experience on a technology and are able to comprehend local firms' scopes of improvement in the production process, provide technical support to local firms. In addition, local firms' level of absorptive capacity is important. Local firms benefit more when the technology gap is large, and the gap can be interpreted as scope of improvement. However, Jordaan's (2012) findings suggest that it is important to separate technology gap and absorptive capacity. Both of these concepts can be independently related to technology spillover between local firms and foreign firms.

If the recipient firm is not ready to manage the state-of-the-art technology, investors will not be comfortable exposing the latest technology to them since both developing and transferring technology require considerable cost. By studying firms in Estonia, Sinani & Meyers (2004) find spillovers of technology to local firms are on average positive and substantive, but the benefits received by a local firm depend on both its own characteristics and that of foreign investments. Large firms having more resources to invest in technology and capacity building are better able to absorb advanced technology from foreign firms and to cope with competition introduced by foreign firms.

The net benefit of foreign direct investment therefore depends on the absorptive capacity of domestic firms, and positive externalities arise only when the domestic firms have some competitiveness (Ferragina and Mazzotta, 2014). Ferragina and Mazzota (2014) note that, through different economic linkages, FDI is likely to have a significant effect on domestic firms, but the effect is heterogeneous across sectors. On the other hand, industry structures and the policy environments in the host countries are important determinants of the net benefit of FDI (Blomstrom and Kokko 1999). Blomstrom and Kokko (1999) note that the relationship between MNE subsidiaries and host economies varies between industries and countries.

Earlier studies found that it was difficult for intra-industry spillover to affect productivity, as the transfer of technology and know-how to local firms are not of strategic interest to foreign firms (Ferragina and Mazzotta, 2014). In contrast, knowledge spillovers are more likely to occur in inter-industry relationship – through upstream and downstream linkages. When foreign firms are customers of local firms, foreign firms often provide technical and other assistance to ensure a stable supply of high standard products and services. However, absorptive capacity is found to be important in technology transfer through both horizontal and vertical linkages, though the extent may vary.

In most research, FDI has been considered as an important tool for economic development in developing countries because MNEs bring with them a bundle of assets such as technology and scientific skills in addition to financial capital when they set up a facility in a foreign country (Hofmann, 2013; Borensztein et al., 1998; Ernst & Kim, 2002; Fu, 2008; Ayanwale 2007 among others). For instance, FDI in Nigeria contributes positively to economic growth – GDP growth has a positive and statistically significant relationship with FDI, suggesting that as the economy improves, more FDI is attracted (Ayanwale). However, it is essential to channel the flows of FDI towards productive use to benefit from FDI. In another study, Adelegan (2000) find a negative linkage between FDI and economic growth in Nigeria because the flow was not used in any productive purpose but used to supplement consumption.

In addition, the developmental effect of FDI on the domestic economy is not always favorable as noticed by Agosin and Machado (2005). Agosin and Machado (2005) develop a model to understand the effect of FDI on domestic investment and run this model on twelve countries in three developing regions. Interestingly, Agosin and Machado (2005) find that FDI can sometimes crowd out domestic investment instead of crowding FDI in, which casts a doubt on the developmental effect of FDI. This unconventional result seems to have to do with the knowledge gap and absorptive capacity of the host countries. Thus, if recipients do not have the required absorptive capacity, they will not get the spillover benefit of technology from FDI.

Moreover, the benefits of FDI can be positive, negative, or neutral depending on the respective countries' absorptive capacity (Girma 2005; Ayanwale, 2007). Girma (2005) finds econometric evidence of the benefits of geographic proximity and absorptive capacity in technological advancement through FDI. The author notes that absorptive capacity can enhance the benefit from FDI related technology, but the rate starts to decline as the absorptive capacity of domestic firms starts to increase after a threshold level.

Though it may seem surprising, technologically advanced countries may sometimes prefer making direct investment in developing and underdeveloped countries because of uncertainty in those countries to imparting the latest technology with other developed countries (Khanna and Palepu, 2013; Zhao 2006). In this way, investors can retain control over the technology for a relatively long time.

Despite the mixed results of FDI spillover in the earlier research, the absorptive capacities of host firms and those of host countries are required to derive the maximum benefit from FDI spillover (Crespo & Fontoura 2007). Crespo and Fontura (2007) analyze the existence, extent, and dimension of FDI spillover and find that FDI spillover is associated with different types of firm-specific, sector-specific, and country-specific factors, and the most robust empirical result is related to the importance of the absorptive capacity of the domestic firms. Thus, existence of the absorptive capacity is fundamental for deriving the indirect benefit from FDI (Crespo and Fontura, 2007).

By analyzing the regional and global production network, Ernst and Kim (2002) demonstrate that these networks have enhanced international knowledge diffusion and the capability of local suppliers in developing countries to absorb new knowledge. Nonetheless, Ernst and Kim (2002) suggest that the baseline for such knowledge conversion is the absorptive capacity of local suppliers, which determines the effectiveness of the process.

Most importantly, it is not the quality or quantity of the technological knowledge, but the absorptive capacity of the recipients that determines the benefits available from technology transfer through FDI (Marin and Bell, 2006). Marin and Bell (2006) point out that the mere existence of FDI cannot explain the total spillover effect in the host countries. So, receiving a substantial amount of FDI does not ensure the maximum benefit for the host countries. To get the full potential of FDI and its attendant technology, a country needs to have, in particular, a strong innovation system.

Regional innovation system in a country, as a set of networks among agents to facilitate their interaction, enhances the absorptive capacity of a firm and leads to better innovation performance (Lau and Lo, 2015; Yam et al., 2011; Cooke et al., 1997; Braczyk et al., 1998). Cohendet et al. (2010) and Simon (2009) emphasize connectedness by saying that the process of knowledge generation and integration critically relies on the 'middle ground' – networks, communities, and collectives that facilitate the interactions among different actors in the innovation system. Such intermediaries provide firms in different countries opportunities to create linkages with one another and encourage the development of sophisticated knowledge ecosystems. Learning opportunities in such linkages are apparently more prominent as host countries reach more advanced developmental stage (Cohendet et al., 2010; Bathelt and Cohendet, 2014).

However, the emergence of such linkages is not an automatic process but may depend on the actors' decision to connect with other actors (Jackson, 2008; Bathelt and Cohendet, 2014), a phenomenon suggesting that the networks are not endogenous to the contexts. Moreover, the effects of the social networks and the depth of embeddedness in the networks are likely to vary on the basis of local firms' characteristics such as absorptive capacity (Fabrizio, 2009; Uzzi, 1999; Volberda et al., 2010). Social embeddedness, network position, and other factors are related to the absorptive capacity and may show different effects on the various dimensions of absorptive capacity (Volberda et al.,2010).

Since local firms and organizations are the basic elements in a regional innovation system, their absorptive capacities determine the overall absorptive capacity of the host region (Fu, 2008). In some studies, absorptive capacity is measured by using the technology gap between the foreign firms and local firms (Sanchez-Sellero et al., 2014; Jordaan, 2012). Nonetheless, a substantial part of the literature about technological advancement and FDI considers R&D and human capital as determinants of absorptive capacity (Narula & Marin, 2003; Keller, 2004; Marin & Bell, 2006; Girma, 2005 among others).

However, almost all of the studies on technological advancement and absorptive capacity have been done using firm level or industry level data in different countries. As a result, there is no standard measurement that permits operational use of the variable absorptive capacity in the country level. Additionally, the requirement for absorptive capacity might be different at the country level because each country has different advantages to offer as well as different demands to fulfill. For instance, Pisano & Shih (2009) point out that the government, domestic firms, and MNEs all contribute to improve the collective knowledge and the technology status of a country. Pisano and Shih (2009) also note that local firms and MNEs are interested more in commercial and applied research, while governments spend more on basic research.

Considering the varying R&D interests of different parties, the importance of diverse knowledge, and the importance of communication to make such knowledge useful (Hidalgo et al., 2007; Perugini et al., 2008; Pisano and Shih, 2009; Hausmann et al., 2014), this research considers knowledge complexity or knowledge intensity of a country as a determinant of absorptive capacity of that country.

Accordingly, to analyze the role of absorptive capacity, this research uses R&D (aggregate expenditure in the country level), human capital, and knowledge intensity as the determinants of absorption capacity in the country level. The following sections discuss each of the determinants of absorptive capacity.

2.6.2 Research and development

Literature reviewed in earlier sections suggests that the pre-existing base of knowledge is associated with the way of technological advancement (Porter, 2000; Ferragina & Mazzotta, 2014). Besides, it is difficult to measure the benefit from FDI and related technological advancement without having local facilities, and FDI tends to flow to places where local capabilities are strong (Lall and Narula 2004). The authors note that there is no conflict between inward foreign direct investment and domestic capabilities because the ability of the host economy to benefit from FDI linkages depends crucially on the technological capability of the recipients.

R&D is generally considered important for the development of new knowledge and the improvement of the existing knowledge base (Narula & Marin, 2003; Marin & Bell, 2006). This role of R&D is more direct and generally recognized, but R&D can have another less recognized indirect role –ability to contribute to the firms' absorptive capacity (Cohen and Levinthal,1989: Griffith, 2003: Kinoshita, 2000). The existing micro-economic literature on R&D, so far, underestimates the "second face of R&D" as absorptive capacity in non-frontier countries (Griffith, 2003).

Cohen and Levinthal (1989) recognize this indirect role of R&D saying that it enhances the firm's ability to absorb existing information from the environment as well as generating new information, and they point out that innovation developed on the basis of a well-established body of knowledge diffuses more rapidly than that developed on the basis of a totally new and recently developed body of knowledge. Cohen and Levinthal (1989) also emphasize that if domestic firms are not equipped with the desired absorptive capacity and ready to internalize the new knowledge, FDI will not be an effective way to upgrade technology.

Regardless of the size of firms and the location of production, firms need to invest in basic research to develop the ability to recognize, exploit, and assimilate knowledge produced by others. Cohen & Levinthal (1989 & 2000) argue that if absorptive capacity is important, and R&D contributes to it, then whatever conditions a firm's ability to build absorptive capacity should also affect R&D spending of that firm. From the similar reasoning, it is possible to say that whatever guides firms' R&D also has some effect on absorptive capacity. Absorptive capacity generated by a firm's internal research is related to the ability of the firm to make use of connections to external knowledge sources, and network connections do result in a faster pace of innovation (Fabrizio, 2009).

The literature suggests that the intensity of R&D activities triggers technological change and expand new knowledge that eventually improves a location's capacity to understand new knowledge and to improve local knowledge base. In a country level analysis of host countries, R&D expenditures enhance the absorption of technological knowledge from FDI (Bodman & Le, 2013). Similarly, Griffith (2003) finds R&D to play an important role in promoting the absorption and imitation of innovation from more technologically developed countries.

The literature also suggests that technology gap, in terms of R&D, is related to the extent of technological advancement. A host country, by encouraging domestic R&D activities, can push forward the local technology frontier which will eventually attract high-tech FDI (Saggi, 2002). The author argues that local capabilities provide fundamental background knowledge needed to transfer more advanced technologies in a cost-effective manner, and the quality of technology transferred through FDI is linked to the rate of innovation and imitation. His study shows that, due to different levels of technology and local capability, a large technology gap limits FDI flow to low quality levels in some markets, while a small technology gap permits FDI at high quality levels in other markets.

The reasons and roles of R&D activities may vary according to industry, market condition, institution etc. Moreover, R&D activities require skilled personnel to carry on the pursuit of knowledge and maintain a competitive position. For example, the pace of advancement of a field affects the R&D activities of a firm in developing absorptive capacities because the faster the pace of knowledge creation, the larger the staff required to keep abreast of latest knowledge developments (Cohen & Levinthal, 2000). Because of this circumstance, the recipients may not always be in a position to get the benefit of knowledge spillover from FDI. Recipients need both R&D facilities and competent personnel to utilize the knowledge. The following section discusses the literature regarding human capital.

2.6.3 Human capital

Technological innovation and development are important to gain superiority in the international arena, but successful economic development is contingent upon the availability of capital and human resources among other resources. Isolated knowledge of individuals in a society does not contribute much in the prosperity of a society, but the prosperity depends on how the individuals communicate and recombine their knowledge to create a larger variety of smarter and better products (Hausmann et al., 2014). Personnel in an organization can utilize their prior related knowledge to shape future outcomes such as competitive advantage, innovation, and firm performance (Volberda et al.,2010; Fu, 2008). Thus, it is important to understand the role of human capital in knowledge creation and absorption from a network approach.

There need to exist adequate human capital in the recipients' side to understand the tacit knowledge and implement the technology to develop local knowledge (Narula & Marin, 2003; Marin and Bell, 2006; Xu, 2000; Borenzstein et al., 1998; Nakandala, 2008; Gorg and Greenaway, 2004). Codified knowledge can easily be transferred between parties in different settings, but absorptive capacity of recipients to get familiar with external knowledge and to apply that knowledge internally is of crucial importance (Cohendet and Meyer-Krahmer, 2001). As Amesse & Cohendet (2001) suggest, to appropriate the result of academic research, even if it is codified, one has "to know the code".

Technological advancement is not about acquisition of hardware or tangible products only because technology can be embodied in products, processes, and persons, and all three of these components of technology transfer involve human resources (Tung, 1994). In the case of product-embodied technology, there must be qualified personnel on both suppliers' and recipients' side to determine what kind of technologies to transfer and what kind of modifications are required to adopt the new technologies. In the case of process-embodied and person-embodied technologies, there need to exist adequate human capital on the recipients' side to understand the tacit knowledge and implement the technology in local firms.

The literature suggest that movement of people is a key mechanism of technology transfer (Radosevic, 1999). For instance, a qualified human capital can be achieved by exchange programmes with research organizations (Cohendet and Meyer-Krahmer, 2001). The common way knowledge spillover happens is through labor turnover because the employees take the internalized knowledge with them when they leave foreign firms and move into domestic firms (Narula and Marin, 2003). However, this internalized knowledge will be of no use to the recipients unless they have the necessary facilities to make the knowledge useful. Narula and Marin (2003) find that recipients that have a larger investment in absorptive capacity, have more efficiently internalized the knowledge coming in through spillover.

However, existence of human capital alone does not guarantee the technological development of a country, proper deployment of human capital is important, too. Besides R&D activities, human capital should also engage in the manufacturing areas where the technologies are being used. To understand the knowledge embedded in a product, people must have a working understanding of that knowledge (Hausman et al., 2014). With sufficient skill and experience, one can understand the technology even when it is incomplete (Nakandal, 2008). Thus, the recipients must have adequate level of technical abilities whereby they can capture the knowledge from FDI spillovers and use it to develop local knowledge base.

Human capital and its continuous upgrading are crucial to gain global competitiveness such as technology and finance (Tung, 1994). A country will not benefit from technology transfer through FDI if the country's absorptive capacity in terms of stock of human capital remains unchanged, (Keller, 2004). Similarly, FDI enhances productivity growth in a host country when that country reaches a human capital threshold (Xu, 2000). By examining the link between FDI and human capital development, Ritchie also (2000) concludes that the mere existence of FDI does not transfer the latest technology and scientific skills to the host economy. Accordingly, a pool of skilled human capital is certainly required to attract FDI and derive the subsequent spillover benefit.

Since R&D and human capital are of significance importance to exploit technological knowledge from FDI, these two are frequently defined in the literature as the determinants of absorptive capacity. However, some studies suggest that sectoral specialization also plays a crucial role in attracting and getting spillover benefits from FDI (Hidalgo et al., 2007; Perugini et al., 2008; Pisano and Shih, 2009; Hausmann et al., 2014). In other words, diverse knowledge of a country determines that country's ability to exchange information with others and expand the existing knowledge base. Consequently, this thesis introduces a new determinant of absorptive capacity – "knowledge intensity" of a country to determine the relationship between its knowledge base and its technological advancement. The following section discusses studies about the significance of knowledge diversity in ameliorating the technology status of a country.

2.6.4 Knowledge intensity

To get the benefit of technology spillover from FDI, there need to exist linkages among foreign and local firms. Most often such linkages depend on sufficient levels of R&D and human capital to complement one another. However, Perugini et al. (2008) argue that education and R&D activities are not the only deciding factors in receiving the spillover benefit. Perugini et al. (2008) emphasize that sectoral specialization also plays a crucial role along with other factors.

Sectoral specialization is often considered an important factor in determining the flow of FDI since investors tend to invest in the same industry (Kinoshita,2000). The reason for such tendency is the availability of skilled labor and a favorable environment for a particular industry (Pisano and Shih, 2009). A sufficient number of employees belonging to an industry, whether in some specific regions or in the country as a whole, could reflect sectoral knowledge spillover and could also be a sign that significant knowledge about some economic activities is accumulated (Perugini et.al., 2008; Pisano and Shih, 2009).

Advanced technological knowledge, in the primary stage, is sparsely distributed among only a few individuals involved in the development of that knowledge (Hausmann et al., 2014). In the later stage, it may be codified and transferred to others, but it is not possible to all types of knowledge and transfer it directly across countries (Keller, 2010). For instance, a designer's expertise in designing a sophisticated product develops through a long period of learning and experience. Bringing, merely, the designers in a new location will not suffice to produce a particular product that requires specific knowledge. The designer must have his workspace with the same facilities as before. In addition, the designer alone cannot accomplish the entire task, but needs other experts with whom he can collaborate.

Such environmental attributes are termed “industrial common” by Pissano and Shih (2009). Pisano and Shih (2009) note that the development of new cutting-edge, high-tech products often depends in some critical way on the common of a mature industry. Experts and firms gather in such places to find jobs and knowledge networks and to be near suppliers and potential partners. Once an industrial common has taken root in a region, a cycle of growth starts (Pisano & Shih, 2009; Porter, 2000).

Though a particular location needs to have some strength to attract FDI, leapfrogging is not possible in upgrading technology and product quality (Hidalgo et al., 2007). Hidalgo et al. (2007) mention that countries need to use their existing knowledge base to improve the quality of production, and they tend to move towards products that are closer to their current specialization. This spatial characteristic has recently drawn a great deal of attention from researchers, who shed light on this from different perspectives. Hidalgo et al. (2007) study the network of relatedness between products and find that higher income products are generally produced in closely connected cores while lower income products are produced in the less-connected peripheral countries. This finding gives an idea about how countries change their specialization from one product to a different product.

Later, Hausmann et al. (2014) argue that the aggregate knowledge of a society does not depend on the knowledge of each individual living in that society. It actually depends on the diversity of knowledge of each individual and the efficiency of the communication among them to make use of that knowledge. In addition, a country’s position in the product space, in terms of the productive knowledge the country has, determines its ability to expand the existing knowledge and grow (ibid). Hausmann et al. (2014) propose a way to measure the amount of diverse productive knowledge a country has and point out that productive knowledge is necessary for a society to hold and enhance knowledge.

2.6.5 Interaction between FDI and absorptive capacity

Firms that have sufficient level of capacity to infer knowledge from the environment are well positioned to take advantage of information available from both internal and external sources. The notion of absorptive capacity and firms' prior knowledge suggest that the existence of knowledge spillover will not affect all firms operating in the industry in the same way. Interaction between foreign presence and firms' R&D expenditure might yield differences in the results (Gorg and Greenaway, 2004).

In other words, there is a possibility that the connection between knowledge spillover from FDI and technology development will be moderated by the level of firms' absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002; Kostopoulos et al., 2011). Kostopoulos et al. (2011) study the absorptive capacity as a moderator of innovation performance and demonstrate the mediating role of absorptive capacity in the relationship between external knowledge flows and innovation – external knowledge inflows advance innovation performance exclusively through absorptive capacity.

So, the outcome of interaction between FDI and absorptive capacity might be different than the sum of their individual outcome. One reason could be that the benefit related to FDI is contingent on the level of FDI. It is also possible that the foreign firms are actually benefitting more than the domestic firms from the FDI relationship because the spillover effect can happen in both directions (Keller, 2004). Thus, domestic firms may not get any significant technology advantage when we consider the overall effect.

For example, Liu (2008) studies the effect of interaction among time, industry, and FDI and notes that domestic firms may not always benefit from FDI. The benefit varies with the industry - industries with high productivity tend to attract most of the FDI. In such cases, the foreign firms, instead of local firms, could be the main beneficiaries of certain FDI relationship. Another issue is time – it is conceivable that a substantial period of time may pass between the commencement of FDI in an industry and its payoff to be evident on the industry. If the foreign firms are the main beneficiaries of the FDI spillover, it is possible that FDI will have no effect or even a negative effect on domestic firms (Liu, 2008).

In another study, Borensztein et. al. (1998) analyze the effects of interaction between human capital and FDI flow and find that FDI leads to higher productivity if a country has a minimum threshold of human capital. This concept of threshold suggests the possibility of no or negative effect of human capital on FDI. Though a higher level of human capital is supposed to result in higher growth, FDI may cause different outcomes. Foreign firms outperform local firms in most areas – higher capital, higher labor productivity, higher wages, etc. Coming to a host country, foreign firms start headhunting for the most competent employees, which results in vacant positions in local firms. Similarly, Nieto & Quevedo (2005), by studying Spanish manufacturing firms, suggest that there exist a positive and significant relationship between absorptive capacity and innovative effort, but the effect can be moderated depending on the types of knowledge and capacities.

From the literature reviewed it is apparent that absorptive capacities - knowledge diversity, expenditure on research and development, and human capital - are important for a country to attract FDI and ameliorate technological knowledge. Earlier studies considered each of these factors independent of others and took their individual effect into account. However, this might not always be accurate. From the literature reviewed, it is possible to argue that absorptive capacities of a country play dual roles – attracting FDI and absorbing technology – to achieve a unique goal of technology development. There is no clear-cut way to distinguish one role from the other, and the roles may interact. For example, availability of skilled labor can attract FDI, but will not necessarily absorb technology and vice versa.

It is possible that the combined effect of changes in these factors is different from the sum of their individual effects. Based on the discussion above, this research develops the following hypothesis.

Hypothesis 2B: The absorptive capacity – measured in terms of R&D, human capital, and knowledge intensity - positively moderates the relationship between network position and technology status of a country.

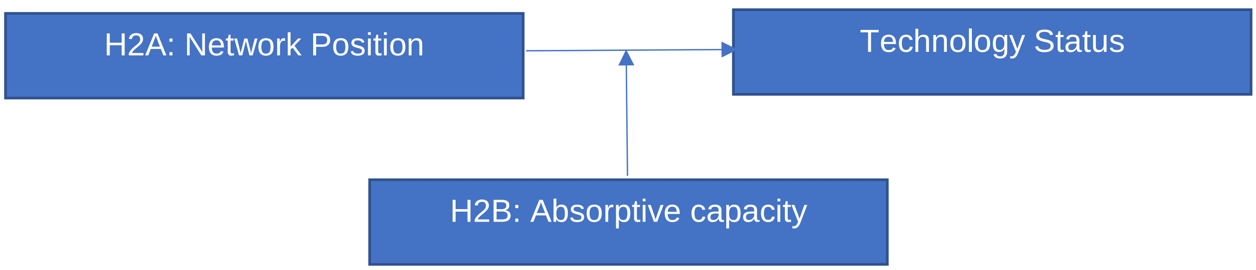
We can graphically summarize the hypotheses as follows:

Network analysis: Hypotheses 1A and1B

H1A: Core-periphery structure in the global FDI network

H1B: Positive relationship between network position and Technology status

Regression analysis: Hypotheses 2A and 2B



3. Methodology and data description

To measure the spillover effect of FDI, most studies use the information of contemporaneous foreign presence in one or several countries. However, using panel data can be the most appropriate framework for two reasons: firstly, panel data studies allow us to investigate the development of host country firms' productivity over a longer period; secondly, such studies allow us to investigate spillovers after controlling for other factors (Gorg and Greenaway, 2004). In addition, the study of absorptive capacity in a dynamic way requires the use of longitudinal research methods and process models, which provide us with a better understanding of the changes over time (Volberda et al.,2010;). Though the longitudinal model studied in this research spans only 8 years, the model enables us to understand a pattern of the relationship between a country's technological advancement and its position in the global FDI network.

This thesis separates the analyses into two parts – network analysis and regression analysis. In order to clearly present the role and position of countries in the FDI network, this thesis uses the UCINET software to plot graphs of binary networks. First, FDI networks, for the years ranging from 2009 to 2016, across 246 countries, including islands and territories, have been prepared to determine the structure of the global FDI network and a country's position in the network. Positions in the FDI networks were computed using the original sample prior to dropping any observations. Later, this network position indicator is used in a regression analysis, using a sample of 150 countries, to examine the relationship between the global FDI networks and the technological advancement of a country.

To establish a network relationship between any two nodes, we need to have information on both of the connected nodes. Bilateral FDI data, about total foreign direct investment stock in the partner countries, is available from the Coordinated Direct Investment Survey (CDIS) conducted by the International Monetary Fund (IMF) for the period from 2009 to 2016. In the IMF database, information on FDI stock for source and destination countries is given. However, in some cases, the values are concealed, to preserve confidentiality of the reporting economy, though there are investment relationships. This thesis uses other information such as the Networked Readiness Ranking (NRR, 1=best), total population, GDP per capita, export, import, R&D expenditure from the Euromonitor International databases. In addition to these, the thesis extracted economic complexity data from the Economic Complexity Observatory (Simoes & Hidalgo, 2011).

3.1 Dependent variable

This research uses Networked Readiness Ranking (NRR, 1=best), available in Euromonitor International database, as a proxy to countries' technology status. NRR is most suitable for this study because it represents the technology readiness of countries', in terms of the capacity to fully leverage information and communication technologies, in order to use existing technology to enhance the productivity of its industries (The Global Competitiveness Report, 2015-2016). Another important feature of NRR, mentioned in the Global Competitiveness Report (2015-2016), is that it considers the importance of firms obtaining access to advanced technology whether or not the technology developed inside a particular country. Above all, the report credits FDI as one of the main sources of foreign technology.

3.2 Independent variable

To assess the role of FDI networks in technological advancement, it is important to understand a particular country's position in the network. First, the research models the global FDI networks (2009-2016). In the FDI network model, each country is considered to be a node, and the existence of investment stock is considered the link between two nodes. Though it is possible to use both FDI flow and FDI stock to build the network, this thesis uses FDI stock to build the network because FDI stock can better measure the magnitude of MNEs than do FDI flows (Xu and Wang 2000; Perugini et al., 2008). In addition to identical financial flows of assets and liabilities, FDI stock also combines equity capital and reinvested earnings and both FDI flow and FDI stock can have negative balances (OECD, 2008).

To build the network, preference is given to indirect measurement of the FDI linkages – regardless of the positive, negative, and concealed values and with no attempt to identify the weight or direction of FDI. As an illustration, figure 3 presents a sample of data analyzed in this thesis to define the investment link.

Figure 3: A sample of data available in the IMF database

FDI (USD, Millions)	Spain	Sri Lanka	Sweden	Switzerland	Tajikistan	Thailand	Togo	Turkey	Uganda	…
Netherlands					0	0		0	0	
Nicaragua	C		0	C	0	0	0	0	0	
Niger	C		C	C	0	0.052984	2.519721	0	C	
Nigeria	C		86.9546	C	0	1.442789	19.72011	0	10.48959	
Norway	4821.453	27.11736	21399.99	C	0	442.1916	32.07002	503	26.96674	
Oman	216.0905	7.08202	0	C	0	4.288118	0	-2	0	
Pakistan	C	11.99989	0	C	10.29256	-0.34609	0	17	-0.07665	
Palau	C		0	C	0	0	0	0	0	
Panama	1137.374	0.954945	0	C	0	230.9026	2.12929	592	C	
…										

The following figure presents a sample of a binary matrix prepared from IMF data and analyzed in this thesis to define the investment linkages. This research uses core-periphery analysis to determine network structure and eigenvector centrality analysis to perceive network positions.

Figure 4: A sample of binary matrices prepared by using the IMF data

FDI	Argentina	Armenia	Aruba	Australia	Austria	Azerbaijan	Bahrain	Belarus	Belgium	…
Argentina	0	1	0	1	1	1	0	0	0	
Armenia	0	0	0	0	0	1	0	1	0	
Aruba	1	0	0	0	0	0	0	0	0	
Australia	1	1	0	0	1	1	0	1	1	
Austria	1	1	0	1	0	1	0	1	1	
Azerbaijan	1	0	0	0	1	0	0	1	1	
Bahrain	0	0	0	1	1	1	0	1	1	
Belarus	1	1	0	0	1	1	0	0		
Belgium	1	1	0	1	1	1	0	1	0	
…										0

Several measures of centrality could be used to determine how centrally located a country is in the network and to understand the structure of the network. For instance, node centrality measures how central a particular node is with respect to other nodes, while degree centrality measures the network activities and points out the influential countries (Kali and Reyes, 2007). Similarly, eigenvector centrality can be a good measure of centrality because it takes into account the centrality of the neighbors of a node while calculating the centrality of that node and provides us with an idea of step by step development of the system.

Eigenvector centrality calculates the eigenvector of the largest positive eigenvalue as a measure of centrality and gives information on the dominance of the largest eigenvalue in the network (UCINET 6 for Windows help contents). This research uses the network eigenvector centrality analysis to determine the position of a country in the global FDI networks and the indicator obtained from eigenvector centrality analysis has been used as the independent variable to perform regression analysis. Following figure is a sample of eigenvectors obtained from network analysis that are used in regression analysis as an independent variable – network position.

Figure 5: A sample of eigenvectors obtained from eigenvector centrality analysis

Country	**EV_2009**	**EV_2010**	**EV_2011**	**EV_2012**	**EV_2013**	**EV_2014**	**EV_2015**	**EV_2016**
…								
Hong Kong	0.147	0.142	0.139	0.137	0.135	0.135	0.133	0.131
Portugal	0.145	0.141	0.139	0.137	0.135	0.135	0.133	0.131
Spain	0.147	0.138	0.135	0.134	0.134	0.134	0.132	0.129
Switzerland	0.144	0.139	0.136	0.135	0.133	0.133	0.131	0.129
France	0.146	0.140	0.138	0.135	0.132	0.131	0.129	0.128
Italy	0.138	0.133	0.133	0.132	0.130	0.131	0.128	0.127
Netherlands	0.147	0.142	0.138	0.130	0.129	0.129	0.127	0.126
Singapore	0.132	0.128	0.126	0.125	0.123	0.126	0.123	0.126
…								

3.3 Control variables

This research uses several controls to maintain consistency with previous studies (Ferrier, 2014; Deng and Xu, 2015; Xu, 2000). To begin with, this research controls for GDP per capita (USD Thousand) because it is an important variable that can affect a country's industrial structure. It is evident in the literature that almost all technologically developed countries are also economically developed countries, and the development status of a country also determines the ability of a country to invest in R&D and education (Keller, 2004; Cooke, 2001; Hermes and Lensink, 2003). Domestic financial system affects growth of a country through the level of technology (Hermes and Lensink, 2003) and economically high performing regions have innovation systems of great sophistication (Cooke, 2001).

Next, this research controls for the effect of trade and trade openness to better understand the relationship between foreign direct investment and technological advancement. Though international trade does not always result from the international differences of technology or factor endowments, it is an important way of exchanging goods and services across countries, and the effects are similar to labor force growth and regional agglomeration (Krugman, 1979). Trade is measured as the total value of import plus export (USD Thousand). Similarly, trade openness of a country is related to both the perception of MNEs' about a country's business environment and their investment decisions. Trade openness is considered as the ratio of total trade to GDP in the literature (Deng and Xu, 2015) as a measure of trade openness.

Though MNEs sometimes may prefer to go to a location with weak intellectual property rights (Khanna and Palepu, 2013), the literature suggest that there should be an adequate protection of intellectual property rights to ease the concerns of foreign companies about introducing advanced technology (Tung, 1994). Establishment of property rights – in particular, intellectual property rights – is crucial to attract high technology FDI in a country (Hermes and Lensink, 2003). Consequently, this thesis controls for property rights by using the property rights index in which higher score, between 0 and 100, means better protection of property rights.

To substantiate the analysis further, this research uses research and development expenditure (R&D), human capital, and knowledge intensity as the determinants of absorptive capacity and controls for the effect of these factors on a country's technology status. Thence, this research controls for the expenditure on research and development (R&D). Expenditure on R&D is measure as total intramural expenditure on R&D

performed on the national territory. It includes R&D performed within a country and funded from abroad but excludes payments made abroad for R&D.

Next, this research controls for human capital. Human capital, in earlier studies, is considered using a traditional higher education indicator: the population aged over 15 with upper secondary and post-secondary non-tertiary levels of education, and the population aged over 15 with tertiary level education (Perugini et al., 2008). Following those studies, this research uses the Human Capital variable measured by average years of total school attainment of the population aged 15 years and over.

Fifth, this research controls for the knowledge intensity of a country. Earlier studies have used the classical Balassa Index, a normalized export share compared with that of a group of reference countries, as a proxy for tacit knowledge accumulated in the labor force (Perugini et al., 2008). Though the Balassa index is widely used in the literature to measure country-sector specialization, it has some limitations. The index is calculated by observing trade flows and considering all the factors that affect trade flows, but it cannot isolate exporter-sector specific factors (Leromain and Orefice, 2014).

Thus, to overcome this issue, this research introduces another index – Economic Complexity Index (ECI), proposed by Hausmann et al. (2014) – as a measure of the knowledge intensity of a country. Economic complexity reflects the amount of knowledge that is embedded in in the productive structure of an economy. Economic complexity is calculated by using export data, but the significance of this measure is beyond that of export, trade openness, or the size of a country (Hausmann et al., 2014).

The following table describes the variables used in this thesis and the data sources.

Table 1: Definitions of variables and data sources

Variable	Description	Source
NRR	Networked Readiness Ranking (NRR, 1= best)	Euromonitor International
GDP_PC	GDP per capita (USD Thousand)	
Trade	Value of total trade (USD Thousand)	
Trade openness	Ratio of total trade to GDP	
Property rights	Values of score between 0 and 100 where higher scores means better protection of property rights	
Research	R&D expenditure (aggregate in the country level)	
Human capital	Population aged 15 and over	
Network position	Value of eigenvector	Eigenvector centrality analysis (Ucinet 6)
Knowledge intensity	Economic Complexity Index (ECI) that measures knowledge intensity of a country	Economic Complexity Observatory
NP_RD	Interaction between network position and R&D	N/A
NP_HC	Interaction between network position and human capital	
NP_KI	Interaction between network position and knowledge intensity	

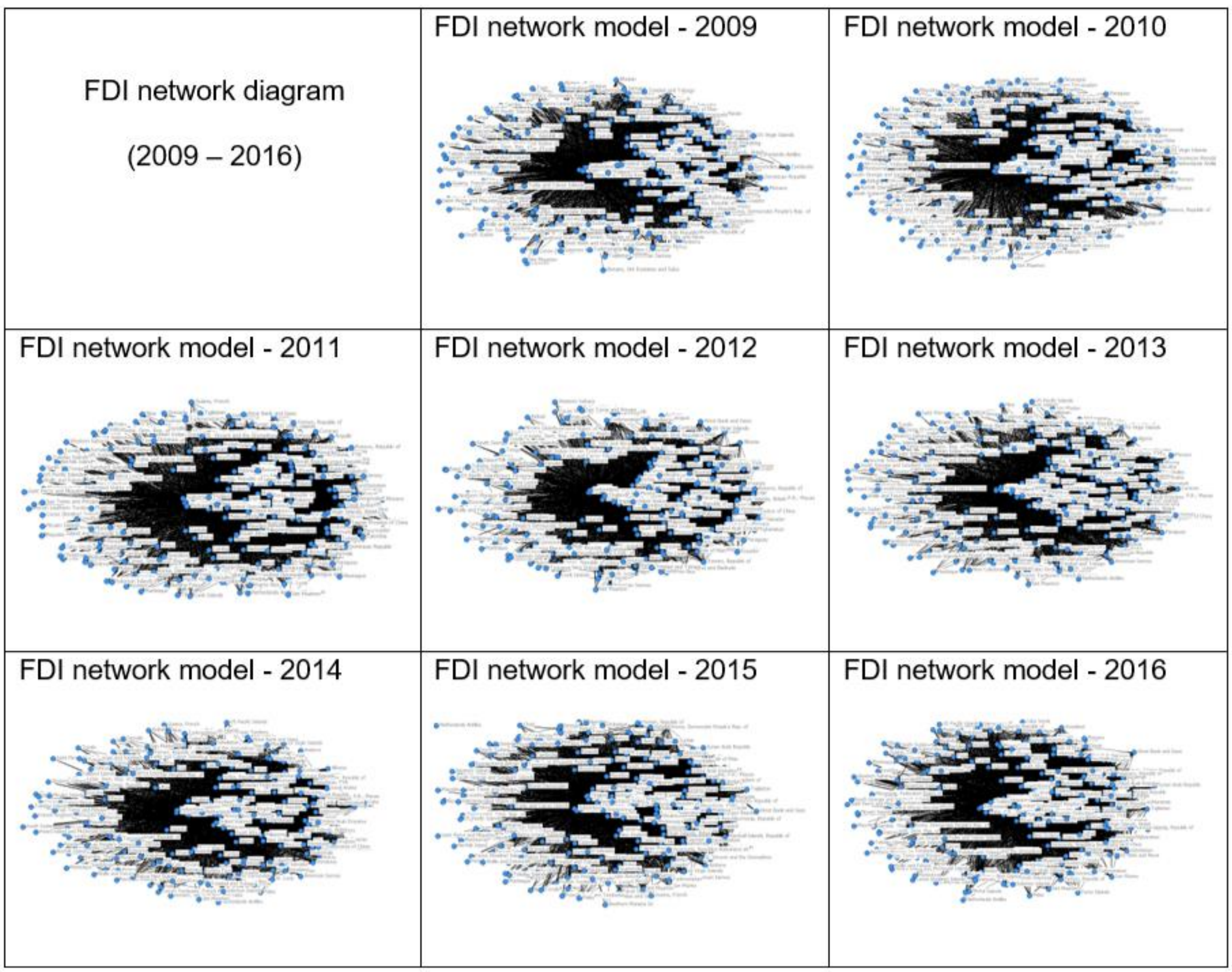
4. Results and discussion

4.1. Results

4.1.1 The global FDI network

FDI network diagrams constructed using binary matrix of FDI linkages visually describe the global FDI networks and provide preliminary indication of core-periphery structure in the networks.

Figure 6: FDI network diagrams of 2009-2016



In the diagrams of FDI networks, most of the countries that had been dominant in the FDI network in 2009 were still dominant in 2016. Next, the findings of core-periphery analysis demonstrate that the FDI networks are hierarchical with a core-periphery structure. The measure of goodness of fit - final fitness of all the models are close to 1 (0 means bad fit, 1 means excellent fit). The density matrices of the models also report a good fit – close to 1. The matrices report a “core” of countries that are closely connected to one another (1,1 block). Some countries are also grouped as “peripheral” in the sense that they have fewer linkages among themselves (2,2 block). The findings support hypothesis 1A of this research.

Figure 7: Simple Core/Periphery model of the global FDI network (2009-2016)

Year	**Final fitness**	**Density matrix**	**Year**	**Final fitness**	**Density matrix**
2009	0.890	1 2 ------- ------- 1 0.898 0.306 2 0.306 0.014	2013	0.889	1 2 ------- ------- 1 0.909 0.307 2 0.307 0.021
2010	0.893	1 2 ------- ------- 1 0.905 0.297 2 0.297 0.016	2014	0.887	1 2 ------- ------- 1 0.917 0.321 2 0.321 0.022
2011	0.878	1 2 ------- ------- 1 0.901 0.313 2 0.313 0.021	2015	0.879	1 2 ------- ------- 1 0.906 0.327 2 0.327 0.024
2012	0.883	1 2 ------- ------- 1 0.904 0.312 2 0.312 0.021	2016	0.889	1 2 ------- ------- 1 0.926 0.350 2 0.350 0.024

It is also evident from the findings of core-periphery analysis that the core countries have a relatively higher technology level than that of the peripheral countries, which is in support of hypothesis 1B. Following table presents some of the countries network positions and their technology status (NRR, 1= best).

Table 2: A random sample of some countries' network positions and technology status

Year / Country	2009		2010		2011		2012		2013		2014		2015		2016	
	NP	**NRR**	**NP**	**NRR**	**NP**	**NRR**	**NP**	**NRR**	**NP**	**NRR**	**NP**	**NRR**	**NP**	**NRR**	**NP**	**NRR**
Switzerland	√	5	√	4	√	4	√	5	√	6	√	6	√	6	√	7
Singapore	√	4	√	2	√	2	√	2	√	2	√	2	√	1	√	1
USA	√	3	√	5	√	5	√	8	√	9	√	7	√	7	√	5
Australia	√	14	√	16	√	17	√	17	√	18	√	18	√	16	√	18
Japan	√	17	√	21	√	19	√	18	√	21	√	16	√	10	√	10
Norway	√	8	√	10	√	9	√	7	√	5	√	5	√	5	√	4
Canada	√	10	√	7	√	8	√	9	√	12	√	17	√	11	√	14
Hong Kong	√	12	√	8	√	12	√	13	√	14	√	8	√	14	√	12
Iceland	**×**	**7**	**×**	**12**	**×**	**16**	√	**15**	√	**17**	√	**19**	√	**19**	**×**	**16**
Mexico	√	**67**	√	**78**	√	**78**	√	**76**	√	**63**	√	**79**	√	**69**	√	**76**

In the table, NP stands for network position and NRR stands for Networked Readiness Ranking – the technology status measurement used in this research. Among the countries present in the table, most of the countries have been in core position in the global FDI network and have had higher technology status throughout the period of study. Only exceptions are Iceland and Mexico. Iceland has been maintaining higher technology status throughout the period though the country has not always been in a core position. Contrary to the expectation, Mexico has always been in a core position in the network, but the country's technology status is not impressive.

This research checks for the robustness of the network analysis by computing the ratio of largest eigenvalues to the next largest eigenvalues. For the centrality measure to be robust, the ratio must be at least 1.5 and preferably 2.0 or more. In this case, the ratios are always around 4 for all the models, and the ratio increases over time. The following table presents robustness of eigenvalues from 2009 to 2016.

Table 3: Robustness of eigenvalues

Year	**Largest Eigenvalues**	**Second Largest Eigenvalues**	**Ratio (Robust if ratio>1.5)**
2009	86.193	21.811	3.952
2010	88.941	20.628	4.312
2011	92.143	20.693	4.453
2012	92.936	20.080	4.628
2013	94.570	20.418	4.632
2014	94.716	20.418	4.639
2015	97.257	22.174	4.386
2016	97.922	20.104	4.871

Therefore, the results of network analysis support hypotheses 1A – that the global FDI network has a core periphery structure, and 1B – core countries in the global FDI network are more technologically advanced than the peripheral countries. All the results have been robust according to robustness analysis.

4.1.2 Network position and technology advancement

Finally, to understand the relationship between countries' technology status and network position, this research uses random-effects ordered logistic regression analysis because the dependent variable (measure of technology status) – NRR is an ordinal variable (Networked Readiness Ranking, 1=best). All the analysis in this part uses STATA statistical software. The following figure reports descriptive statistics of the variables used in this study.

Figure 8: Descriptive statistics of the variables studied

Variable		Mean	Standard Deviation	Minimum	Maximum	Observations
NRR	Overall	65.21	42.95459	0	148	N = 1200
	Between		36.625	2	139.375	n = 150
	Within		22.6172	-44.29	173.585	T = 8
Network Position	Overall	0.0693975	0.0343634	0.011	0.147	N = 1200
	Between		0.0339948	0.013625	0.137375	n = 150
	Within		0.0056518	0.0176475	0.1045225	T = 8
GDP Per Capita	Overall	20.04758	20.93401	0	146.9	N = 1200
	Between		20.84423	0.75	133.15	n = 150
	Within		2.507434	-1.702471	37.53508	T = 8
Total Trade	Overall	2.18e+08	5.16e+08	0	4.31e+09	N = 1200
	Between		5.12e+08	0	3.61e+09	n = 150
	Within		7.78e+07	-1.18e+09	9.19e+08	T = 8
Trade Openness	Overall	0.4063112	0.3279275	0	2.583935	N = 1200
	Between		0.3215956	0	2.446469	n = 150
	Within		0.0686769	-.0.0701212	0.7292674	T = 8
R&D	Overall	1.07e+07	4.63e+07	0	5.03e+08	N = 1200
	Between		4.42e+07	0	3.99e+08	n = 150
	Within		1.44e+07	-3.88e+08	1.29e+08	T = 8
Human Capital	Overall	30507.63	117820.6	0	1135338	N = 1200
	Between		118108.9	0	1108432	n = 150
	Within		3663.664	-26052.22	87254.88	T = 8
Knowledge Intensity	Overall	0.0310559	0.8327581	-2.79136	2.59625	N = 1200
	Between		0.7889197	-1.712244	2.305442	n = 150
	Within		0.2733594	-1.653068	1.7433	T = 8
Property Rights	Overall	45.39583	24.68968	0	95	N = 1200
	Between		24.54295	0	95	n = 150
	Within		3.277304	28.52083	72.27083	T = 8

Due to the nature of the dependent variable, the research expects to find a negative sign in all the analysis. The negative sign denotes a positive relationship in this analysis because our dependent variable NRR is a ranking in which the lower the value the better the status (NRR, 1=best). The correlation statistics in the following figure show that all the variables used in this study are negatively correlated with technology status as expected. Specifically, the highly negatively correlated NRR suggests that the technology status of a country will improve with the increase in the network position of a country. This correlation analysis provides Preliminary support to do regression analysis.

Figure 9: Correlation statistics (star at 10% significance level)

	Variables	1	2	3	4	5	6	7	8	9	10
1.	NRR	1.0000									
2.	Core Periphery	-0.4479*	1.0000								
3.	Network Position	-0.5272*	0.8535*	1.0000							
4.	GDP per capita	-0.5848*	0.3823*	0.4965*	1.0000						
5.	Total Trade	-0.3180*	0.3694*	0.4976*	0.3066*	1.0000					
6.	Trade Openness	-0.4301*	0.3459*	0.4438*	0.5136*	0.1936*	1.0000				
7.	Property Rights	-0.6108*	0.4986*	0.5901*	0.6163*	0.3204*	0.5736*	1.0000			
8.	R&D	-0.2000*	0.2248*	0.3026*	0.1666*	0.8833*	-0.0286	0.1763*	1.0000		
9.	Human Capital	-0.0462	0.2061*	0.2629*	-0.0363*	0.6136*	-0.1269*	-0.0289	0.6027*	1.0000	
10.	Knowledge Intensity	-0.4960*	0.5425*	0.6061*	0.4298*	0.4679*	0.4704*	0.5650*	0.3245*	0.1265*	1.0000

Next, we conduct regression analysis. The analysis is done by preparing three models, adding different variables step by step, to understand the effects of different variables. In the model A, only control variables – GDP per capita, total trade, trade openness, and property rights are included. In model B, determinants of the absorptive capacity – R&D, human capital, and knowledge intensity are added. In model C, an interaction between FDI network position and each of the determinants of absorptive capacity is included. The following is the results from the regression analysis.

Figure 10: Results of regression analysis

Random-effects ordered logistic regression

Variables	Mode A	Model B	Model C
NRR			
Network Position (NP)	**-16.537****	**-17.151****	**-17.839****
	(5.55)	(5.77)	(5.93)
GDP per capita	-0.048***	-0.047***	-0.048***
	(0.01)	(0.01)	(0.01)
Total Trade	-0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)
Trade Openness	0.092	0.061	0.183
	(0.50)	(0.53)	(0.54)
Property Rights	-0.056***	-0.059***	-0.056***
	(0.01)	(0.01)	(0.01)
R&D (RD)		0.000	-0.000
		(0.00)	(0.00)
Human Capital (HC)		-0.000	-0.000
		(0.00)	(0.00)
Knowledge Intensity (KI)		0.197	1.107**
		(0.17)	(0.40)
NP_RD			0.000
			(0.00)
NP_HC			0.000
			(0.00)
NP_KI			**-12.528***
			(4.91)
Prob >= chibar2	0.0000	0.0000	0.0000
Wild chi2	160.57	158.11	160.43
Chibar2	402.14	386.09	369.37
Number of observations	1200	1200	1200
Sigma2_u			
Constant	5.302***	5.486***	5.722***
	(0.83)	(0.87)	(0.89)

*p<0.05, **p<0.01, ***p<0.001

All the models are globally significant suggesting that the variables in this analysis do are significantly associated with the technology status of a country, and the such association cannot be explained by chance. The Wald chi2 values – in all the models – tell us that none of the coefficients are zero in these analyses. Besides, there is enough variability in the data to favor random-effects ordered logistic regression over standard ordered logistic regression.

Controlling for GDP per capita, total trade, trade openness, and property rights in the model A, this analysis finds support for hypothesis 2A which states that a country's position in the FDI network is positively associated with that country's technology status (coef. -16.537, the negative sign indicates improvement in the NRR).

To explore more, the analysis adds three determinants – R&D, human capital, and knowledge intensity - of absorptive capacity in model B. The model still supports the hypothesis, in fact, somewhat more strongly (coef. -17.151 compared to coef. -16.537 in the first model, the negative sign indicates improvement in the NRR). Among the determinants of absorptive capacity, only human capital has a negative coefficient, but none of the P-values is significant in this model, suggesting that the outcome can be explained by chance. However, the stronger coefficient of network position in model B implies the association between absorptive capacity and the process of technology absorption from FDI.

The regression model A and model B assume that the effect of each explanatory variable is independent that of the other variables. However, the literature suggests that this might not always be the case, these variables may interact and change results. Accordingly, to understand whether the effect of a simultaneous change in FDI network position and the determinants of absorptive capacity is different from the sum of their individual effects. In the model C, an interaction between FDI network position and each of the determinants of absorptive capacity is considered.

The findings show that a country's network position is still important regarding its technology status (coef. -17.839 compared to coef. -16.537 in the first model and coef. -17.151 in the second model, the negative sign indicates improvement in the NRR). Among the three models, the coefficient of network position is strongest in model C.

In case of the interaction between network between network position and the determinants of absorptive capacity, none of the traditional determinants of absorptive capacity – R&D and human capital – is significant, but the interaction between knowledge intensity and network position is significant. Furthermore, the interaction variable has a negative coefficient as expected.

4.2 Discussion

The process of technological advancement have long been of research interest to scholars, and much of the conventional understanding of the process hinges on direct channels of technology transfer. However, there is no single way to transfer technology because technology transfer involves not only the product or service specific know-how but also the know-how of higher-level engineering and technical personnel if needed (Baranson, 1970; Farhang, 1997). The question thus emerges as how to better understand the process of technological advancement, and whether recipients' capacities matter. FDI is considered as one of the major channels of technology transfer in the literature with an emphasis on absorptive capacity of the recipients. This thesis substantiates our understanding of the process of technological advancement from a network analysis approach.

This research models the global FDI network – using bilateral FDI linkages among countries – which provides a more nuanced view to understand the relation between a country's position in the global FDI network and its technology status, and the role of absorptive capacity in technological advancement. In the global FDI network, countries are treated as network nodes that are connected to one another through FDI linkages, and preference is given to indirect measurement of FDI linkages regardless of the weight and direction of FDI. FDI networks, for the period from 2009 to 2016, have been operationalized using information on 246 countries, including islands and territories, available in the IMF database.

To begin with, the thesis argues that the global FDI network is hierarchical with a core-periphery structure - hypothesis 1A and that core countries are more technologically developed than peripheral countries - hypothesis 1B. By doing a core-periphery analysis, this research finds empirical evidence for both hypotheses. The finding of core-periphery structure in the global FDI networks is consistent with the notions in the existing literature on FDI and technological advancement. Depending on the advantages available, some locations receive more FDI than other locations do (Casi and Resmini, 2014), and this process results in clusters of specific industries (Porter, 2000; Pisano and Shih, 2009). Eventually, those clusters become flagship of a location that attracts more FDI, and the process goes on. Finding of a core-periphery structure in the FDI network is much alike the findings of Kali and Reyes (2007) and Ferrier et al. (2016), in which they detect a core periphery structure in the trade network.

The finding of the higher technology level of core countries than that of peripheral countries is also consistent with the literature. Because of the costs involved in technology development process, most of the countries cannot implement it on their own but gain access to latest technology through direct and indirect linkages with other countries because network embeddedness facilitates transfer of knowledge (Firtsch & Kauffeld-Mon, 2010; Kali, 2010). The finding – high technology status of core countries' – is in line with the notion that a country's position in the product space, in terms of the productive knowledge a country has, determine its ability to expand the existing knowledge (Hausmann et al., 2014). Similarly, countries that are better connected in the network tend to perform better by quickly adopting the latest technology (Ferrier et al., 2016), and core countries enjoy privileges over the peripheral countries in a network (Benito et al., 2003).

On the other hand, the finding that the technology level of some peripheral countries is surprisingly high might have resulted from other factors such as a country being embedded in some other networks. For instance, Kali and Reyes (2010) note that though the countries that are in central position in the network will be more affected by a financial crisis, such effects can be moderated if the countries are better integrated in the trade network. There could also be some other factors that are associated with the effect of the global FDI network in the technology level of a country. For instance, a recent publication by the IMF (Mallaby, December 2016) suggests that the trend of cross-border capital movement is changing, and the total picture is becoming more complex. In the beginning of globalization, there was a cross border movement of capital, goods, and people. But now, Mallaby (2016) notes, international flows of capital have collapsed, though the cross-border movement of people still marches on. So, it is possible that even if those countries do not receive much FDI, they have enough local to capacities catch up global technological advancement.

Since a country's position in the FDI network may evolve over time, this thesis uses network position indicator obtained from eigenvector centrality analysis to understand how a country's position in the FDI network is related to that country's technology status. This research proposes and find empirical evidence that a country's position in the global FDI network is positively associated with that country's technology status – hypothesis 2A. The finding is in line with the literature confirming that FDI, indeed, is an influential factor in technological advancement (Blomstronm and Kokko, 1989; Xu and Wang, 2000; Keller, 2010; Lall and Narula, 2004; Nakandal, 2008 among others). However, the finding is not in harmony with some studies that cast a doubt on the developmental effect of FDI (Agosin and Machado, 2005; Narula and Marin, 2005). Such unconventional result can be a result of absorptive capacities of host countries because. Benefits from the FDI depend on types of activities undertaken and absorptive capacity of a country (Gugler and Brunner, 2007).

In addition, the thesis argues that the absorptive capacity – measured in terms of R&D, human capital, and knowledge intensity – positively moderates the relationship between network position and technology status of a country – hypothesis 2B. Findings from regression analysis partially support hypothesis 2B. R&D and human capital are not associated with the technology status of a country, but the knowledge intensity is.

As this research finds, R&D and human capital may not appear significant factors in the technology status of a country although both factors are believed to be important in that regard. R&D expenditure might have different results depending on the sources, motives, and industrial environment (Sanchez-Sellero et al., 2014). It is possible that some countries are at the early phase of development – most of the expenditure on R&D is made on infrastructure development such as building lab or buying instrument for the lab. On the other hand, building infrastructure also requires human capital - time and effort from managers. The estimated effects of R&D and human capital may not be as expected when the sample period is too short to allow sufficient time for the technology gain to offset the expenditure made (Liu, 2008).

Another reason for the unexpected finding can be due to different factors such as limited hiring of local employees, little mobility of employees between foreign and local firms, limited linkages among foreign and local firms, no R&D activities by the subsidiary, and few incentives for the foreign firms to diffuse technology (Aitken and Harrison, 1999). It is also possible that the quality of human capital in most of the countries is not high enough to affect the absorptive capacity. For instance, Ayanwale (2007) finds human capital to have a negative relation with FDI in Nigeria and explains that the level of human capital in the country is not sufficient to absorb the technology being transferred via FDI. Thus, the association among R&D, human capital, and the technological advancement of a country may not be visible in the short run.

Nonetheless, the finding regarding R&D expenditure – to not have any significant association with technological advancement – can actually be interpreted as a support for technological advancement through FDI. It is possible for some countries to have a higher technology status without significant spending on R&D if they can access the technology through indirect linkages. International transmission of technology is an "effective alternative" to the international production of knowledge through R&D activities (Archibugi & Michie, 1995).

Finally, the most striking result that emerges from this research is the significant relationship between knowledge intensity and the technology status of a country. This interesting finding calls for the host countries to widen their perspective towards development of local capacities. Although, sectoral specialization and spatial knowledge have been acknowledged for their significance to attract FDI and enhance local knowledge base (Kinoshita, 2000; Perugini et al, 2008; Hausmann et al., 2014; Hidalgo, 2007), none of the study related to absorptive capacity regards spatial knowledge indicator as a determinant of absorptive capacity. In today's knowledge economy, possession of useful knowledge is crucial to strengthen local innovation performance (Turkina and Van Assche, 2018: Bathelt et al, 2004). Besides, productive knowledge or economic complexity of a country can predict future growth and competitiveness of that country (Hausman et al., 2014).

Another significance of this finding is that knowledge intensity can also be considered as measures of governance and institutional quality and competitiveness among other factors (Hausmann et al., 2014). Both of these indicators are important for the foreign investors to feel comfortable in investing, cooperating, and sharing knowledge with local partners. The Economic Complexity Index tries to capture "the total amount of productive knowledge" that is embedded in a society and is related to the diversity of knowledge that a society holds (Hausmann et al., 2014). In addition, knowledge intensive firms can grow and develop innovative projects based on the dynamics of an environment such as specialized knowledge (Cohendet and Simon, 2008). Thus, promoting investment in local knowledge content is crucial to speed up technological development.

In the end, the partial support for hypothesis 2B suggests that there is no one-size-fits-all direction on which capacities are most important for a country to benefit most from technology transfer through FDI. The results, however, point out that there are scopes for a country to get benefit from FDI spillover even when its network position changes by reshaping the factors related to absorptive capacity.

5. Conclusions: policy implications, limitations, and future research directions

To understand the relationship between the global FDI network and technological advancement, this thesis models bilateral FDI among countries as an interdependent network and finds that the global FDI network has a core periphery structure. In the global FDI network, core countries are more technologically developed than peripheral countries. The research argues and finds empirical evidence that a country's position in the FDI network is positively associated with that country's technology status. The research also finds partial support that a country's level of absorptive capacity - measured in terms of R&D, human capital, and knowledge intensity – positively moderates the relationship between a country's network position and the technology status. The traditional indicators of absorptive capacity– R&D and Human capital – are not significantly associated with technological development of a country while knowledge intensity is.

The most remarkable finding in this research is the significance of knowledge intensity in the technology status of a country that gives a nuanced understanding of absorptive capacity that a country can focus on. For instance, the amount of "productive knowledge" available in a country also refers to the state of other activities in that country such as governance and institutional quality and competitiveness. Thence, a country can focus on which activities to focus on to attract technology intensive FDI. Above all, knowing their network position in the global FDI network and technology status, countries can attract FDI from core members of the network that have advanced technology. Doing so will lead to sustainable economic and technological development in the host countries. Countries that are closely connected to one another in the FDI network, can improve the structure of the whole network to ensure an even distribution of international investment.

Since the incidence of positive spillovers from FDI is neither automatic nor unconditional, there is scope for the policy makers to ensure that local firms have the right organizational structures and incentives to develop a sufficient level of absorptive capacity. The obvious policy conclusion to be drawn from this analysis is that policymakers should be proactive in building absorptive capacity in target sectors to attract more FDI in those sectors. Formulating policies that aim at stimulating firms' absorptive capacity can be a valuable complement to the traditional array of policies to enhance innovation performance of the recipients. The contribution of the local capabilities to inward technology transfer is critically affected by overall economic and trade policies (Mowery and Oxley, 1995; Lau and Lo, 2015).

This thesis contributes to the wide literature on FDI, technology transfer, technological advancement, and absorptive capacity from a new perspective – that of network relationships. On the one hand, this research complements the small existing international business literature on network analysis with a particular focus on the global FDI network to understand the structure of the network. On the other hand, this research supplements the existing literature on FDI, technology transfer, technological advancement, and absorptive capacity with the empirical evidence. Most importantly, this research provides insights for the host countries to formulate better policies so as to catch up the technologically developed countries.

Nevertheless, this study is subject to some limitations that give opportunities for future research. Since, there is no widely accepted measure of technology status at the country level, this research uses Networked Readiness Ranking (NRR) as a proxy to measure the technology status of a country. Similarly, in the absence of a clear-cut measurement of absorptive capacity, this research relies on the measures used in firm-level studies to control for absorptive capacity and uses the aggregate information available at country-level of such measures. Another issue is the limited availability of required information on bilateral FDI linkages – the information available in the IMF database is only for 8 years (2009-2016).

Future research using a more clearly defined measure of the technology status and absorptive capacity at the country level and studying a longer period will help validate the findings of this research in a wider context. Though absorptive capacity is crucial for deriving the benefit from diffused technology, there is no clear-cut way to separate diffused technology from local technology at the country-level. The literature discussing the role of absorptive capacities even suggest that this role is not the same everywhere but depends on several other factors. Thus, trying to separate local technology from diffused technology would be an interesting extension of this research. The results might also be different when the reasons for engaging in R&D activities are taken into account. For example, R&D activities aimed at producing new products or services in the market might not have any immediate result while R&D activities devoted to improving existing knowledge i.e. absorptive capacity might have.

Literature suggests that an improvement in a country's network embeddedness allows it to improve its technology status, but it is also possible that an improvement in a country's technology status pushes its firms to conduct more FDI to other knowledge hotspots or large markets (Turkina and Van Assche, 2018; Bathelt, 2001). Thus, an important extension of this research could be analyzing the global FDI network from investors point of view – to analyze the outward foreign direct investment network – to understand the possible issues of endogeneity. Similarly, modeling FDI networks according to countries in different regional block will give a better idea to understand regional development and global economic integration.

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Appendix A: Table A - Key studies on network analysis

Author(s)	Background	Important findings
Jackson (2008)	Social and economic networks	• Advantages of network analysis • Network positions are important • Costs and benefits of associated with network formation
Jackson and Rogers (2005)	Small world networks	• Self-interest of agents in network formation
Easley and Kleinberg (2010)	Social networks	• Dispersion of ideas in a network • Strategic decision making of agents
Granovetter (1983)		• Effects of social structures • New information mainly obtained from weak connections
Albert and Barabasi (2002)	Concepts of networks	• Real networks are far from being random • Network plays role to spread ideas
Turkina et al. (2016)	Aerospace industry	• Network effect is not limited to geography or industry
Turkina and Van Assche (2018)	Aerospace industry	• Geographical proximity does not guarantee the access to positive externalities of a cluster
Ferrier, G. D., Reyes, J., & Zhu, Z. (2016).	Technology transfer in the trade network	• Better connected countries are quick to adopt new technology
Kali, R., & Reyes, J. (2007, 2010).	International trade network	• International trade network has a core-periphery structure • Core countries are more affected by financial crisis • Integration in the trade network might moderate the effect of financial crisis

Appendix A continued

Schiavo, S., Reyes, J., & Fagiolo, G. (2010)	International trade and financial integration	• More countries are involved in the trade network then the financial network
Kastelle, T., Steen, J., & Liesch, P. (2006)	Evolution of international trade	• The effects of globalization is not same across regions
Rauch, J. E. (2001)	Business and social networks	• Networks can either improve or hinder efficiencies in international trade
Benito, G. R., Grøgaard, B., & Narula, R. (2003).	Regional integration	• Integration in a network increases the chance of receiving FDI • Core countries enjoy privileges over peripheral countries
Hidalgo et al. (2007)	Network of relatedness between products	• High-income products are produced in core countries while low-income products are produced in peripheral countries

Appendix A continued

Ernst, D., & Kim, L. (2002)	Production network in knowledge diffusion and local capacity formation	• Global and regional production networks enhance international knowledge diffusion
Cooke (2001)	Regional Innovation Systems	• The nature of a region's innovation system can be determined by analyzing the networking and learning capacity the firms in that region
Uzzi (1999)		• networks can enhance the capability to recognize and assimilate complex ideas • It is easier to transfer tacit knowledge through strong ties
Dhanaraj et al (2004)	Managing knowledge transfer and the role of social embeddedness	• The importance of social embeddedness in transferring tacit and explicit knowledge

Appendix B: Table B - Key studies on technology transfer and technological advancement

Author(s)	Background	Important findings
Baranson, J. (1970)	Technology transfer through MNEs	• MNEs are willing and able to transfer technology through industrial transfer
De La Potterie, B. V. P., & Lichtenberg, F. (2001)	Technology transfer through FDI	• A country's productivity increases if it invests in an R&D-intensive country
Keller (2004, 2010)	International technology transfer (UK and USA)	• FDI stimulates technology transfer • Distribution of technological knowledge across countries is not equal
Helpman (1997)	R&D and productivity	• FDI is a major channel of technology transfer
Lall and Narula (2004)	Role of FDI in economic development	• MNEs tend to go where local capabilities are strong • No conflict between FDI and domestic capabilities
Liu and Wang (2003)	Role of FDI in technological development	• FDI is a gateway to advanced technology to host countries.
Saggi, K. (2002)	Trade, FDI, and international technology transfer	• Positive relationship between FDI and economic growth • Technology diffuses through demonstration, labor turnover, and vertical linkages
Hofmann, P. (2013)	Effects of international trade and FDI on economic growth and technical change	• Motive for FDI is to gain access to foreign firms' knowledge and technology
Borensztein et al. (1998)	Effect of FDI on economic growth	• FDI is an important vehicle for technology transfer
Kokko (1992, 1994)	The role of industry characteristics in technology transfer	• Spillover benefit differs from industry to industry

Appendix B continued

Liu, X., & Wang, C. (2003)	Effects of FDI on total factor productivity	• FDI is a gateway to advanced technology for host countries
Blomström, M., & Kokko, A. (1999)	Effect of FDI on host countries	• MNEs introduce new know-how to local employees
Findlay (1978)	FDI and transfer of technology	• MNEs expose local firms to new technologies
Radosevic, S. (1999)	International technology transfer	• Generation and transfer of technology vary according to form and channel
Djulius, H. (2017)	FDI and technology transfer	• Industry specialization and partnership with foreign companies lead to technology transfer
Wahab et al. (2012)	Concepts of technology and technology transfer	• Both technology and technology transfer have different dimensions depending on underlying theory and application.
Amin and Cohendet (2005)	Geography and innovation systems	• Technological and knowledge base that shape the learning and innovation system of a region vary from country to country • The dense relations of interlinked communities act as the field of innovation
Gorg and Greenaway (2004)	Benefits of FDI and local characteristics	• Gauging the local characteristics and technology gap, foreign investors decide where to invest and what kind of technology to transfer • Adoption of new technology can occur through acquisition of human capital

Appendix B continued

Bathelt and Cohendet (2014)	Knowledge creation, local ecosystems, and linkages to global actors	• The local structure is a crucial condition and reference point for the production and reproduction of advanced knowledge • The dynamics of knowledge creation are mainly the result of the formation of new ideas from interactions within the local ecosystems and the linkages between local and global actors.
Mowery and Oxley (1995)	Technology transfer and innovation systems	• To obtain technology from foreign sources the overall effort to exploit the sources of technology is more important regardless of the channels
Ayanwale (2007)	FDI and economic growth	• FDIs transfer technology to the host country and contributes positively to economic growth

Appendix C: Table C - Key studies on absorptive capacity

Author(s)	Background	Important findings
Cohen, W. M., & Levinthal, D. A. (1989)	Role of R&D in innovation and learning	• Define absorptive capacity • R&D enhances a firm's ability to absorb existing information as well as generating new information
Ferragina, A. M., & Mazzotta, F. (2014)	Indirect effects of foreign firms on the host country (Italy)	• Net benefit of foreign firms depends on the absorptive capacity of local firms
Kinoshita, Y. (2000)	R&D and technology spillover via FDI (Czech manufacturing sector)	• Role of R&D in absorbing technology
Borensztein, E. et al. (1998)	Effect of FDI on economic growth	• FDI contributes to economic growth only when a host country has sufficient level of absorptive capacity
Girma, S. (2005)	Absorptive capacity and spillover from FDI (UK)	• The outcomes of FDI can be positive, negative, or neutral depending on a country's absorptive capacity
Baranson (1970)	Technology transfer through international frims	• Willingness of host country firms and absorptive capacity of host country are important for technology transfer
Marin, A., & Bell, M. (2006)	Technology spillover from FDI (Argentina)	• Human capital is associated with spillover effect
Amesse, F., & Cohendet, P. (2001)	Technology transfer from the perspective of knowledge-based economy	• The quality of technology transfer process depends on the absorptive capacity of the related firms
Hausmann, R. et al. (2014)	Economic complexity and prosperity	• Economic complexity or productive knowledge is necessary to hold and enhance knowledge
Perugini, C., Pompei, F., & Signorelli, M. (2008)	Role of FDI, R&D, and human capital in innovation process	• Sectoral specialization plays a crucial role in attracting and getting benefit from FDI

Appendix C continued

Cohendet and Meyer-Krahmer (2001)	Knowledge codification, innovation, and absorptive capacity	• Absorptive capacity of recipients to get familiar with external knowledge and to apply it internally is of crucial importance
		•
Volberda et al. (2010)	Absorptive capacity and innovation system	• Firms with higher level absorptive capacity have more in-house expertise and utilize their connections with others more efficiently • Social embeddedness and network position affect the absorptive capacity
Lau and Lo (2015)	Regional innovation systems, absorptive capacity and innovation performance	• To improve innovation performance, firms need to have the internal capability to learn and improve, which can be complemented by intensity and proximity of networking
Fu (2008)	FDI, absorptive capacity, and regional innovation capability	• FDI is positively associated with the innovation efficiency in the host region • The development of technological capacities is the outcome of a complex interaction of inventive structure with human resources, technology efforts, and institutional factors
Kostopoulos et al. (2011)	Absorptive capacity, innovation, and financial performance	• External knowledge inflows are directly related to absorptive capacity and indirectly related to innovation • Firms' involvement in innovation collaborations with outside parties enriches their knowledge base

Appendix C continued

Fabrizio (2009)	Link between absorptive capacity and innovation systems	• A firm's absorptive capacity affects its capacity to connect to external knowledge sources • The effects of network structures are likely to vary as a function of local firms' absorptive capacity
Lane et al. (2006)	Absorptive capacity	• Suggest three process dimensions of absorptive capacity - explorative learning, transformative learning, and exploitative learning.
		•
Narula and Marin (2003)	FDI spillover, absorptive capacity, and human capital	• Domestic firms need have a minimum level of sophistication to internalize the new knowledge and to upgrade technology status • Absorptive capacity can be said a result of two interdependent factors – R&D and human capital
Crespo and Fontoura (2007)	Determinant factors of FDI spillovers	• The existence of the absorptive capacity fundamental for getting the indirect benefit of FDI