Knowledge, Location and Trade

PETER WARDA

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Moreover, Papers 3 and 4 address how knowledge embodied in exported goods and codified knowledge in patents are affected by changes in new routines. Paper 3 analyzes how firms' knowledge absorption capacity affects the development, adoption and introduction of new export products among Swedish manufacturing firms. Finally, the focus in Paper 4 is on innovations measured in terms of local patents production in European regions. In this paper, we analyze how the local patents production in a European region benefits both from local R&D inputs in its own region and from spillovers of R&D inputs in other European regions.

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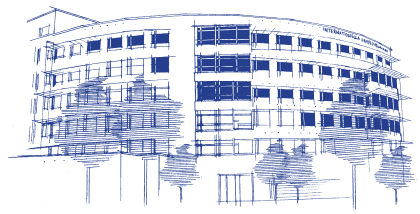

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Jönköping, November 28, 2014

Peter Warda

Abstract

The purpose of this thesis is to analyze how knowledge contained in traded goods influences firms' demand for labor, and how knowledge-rich routines across space affect the innovative performance in firms and regions.

Four research questions are presented that address how knowledge can travel in space. Each research question forms an individual paper in the thesis and can be read separately. The first part of the thesis gives a general introduction and outlines the theoretical background and motivation for the research questions examined in Papers 1 through 4.

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Introduction and Summary of the Thesis

1 Introduction

The purpose of this thesis is to analyze how knowledge contained in traded goods influences firms' demand for labor, and how knowledge-rich routines across space affect the innovative performance in firms and regions.

In recent decades, we have experienced fundamental shifts in the location of world production of both final and intermediate goods. Initially, mainly manufacturing was involved in this restructuring, but increasingly also services including R&D have been affected (Blinder 2006). These shifts have been achieved through increases in foreign direct investment (FDI) and in international trade, especially in the form of offshoring. An example using UNCTAD data is represented in McCann and Ács (2009: p. 19), where about 78,000 multinational firms, with more than ten times as many foreign affiliates, have been involved in some form of relocation. Along with the expansions of multinational firms, world merchandise trade has increased almost at an exponential pace (WTO 2010: p. 13). These developments in FDIs and in international trade are motivated by a number of global drivers.

There are five important global drivers that have facilitated firms' FDIs and their ability to perform offshoring via international trade. First, improved infrastructure, in terms of better highways, airports, harbors, railroads, and installations of fiber optic cables, has increased the global accessibility for networking activities. Second, advances in information and communications technology have made it easier for firms to communicate within their economic networks. Third, the GATT has since 1947 promoted lower tariff rates and trade quotas in member countries, and thus pushed international trade flows to an augmented level. In addition, regional blocs (such as NAFTA, EU and ASEAN) prove to have a significant role in promoting trade as they act to reduce further the tariff rates and trade quotas, and thus induce more countries to globally integrate with each other via trade links. Fourth, the multinational firms have since the mid-1960s acted in favor of internationalizing their capital and labor stocks, thus making production inputs globally available. Finally, reduced transportation costs in container shipping and other means of distribution have made it possible to move goods globally at a lower cost per unit transported.

Another observation we have experienced lately is an increased interest in research that examines how internal and external knowledge sources interact with various performance measures of firms and of regions (Gråsjö 2008, Andersson and Johansson 2012, Johansson et al. 2014, Johansson and Lööf 2014, Lööf and Nabavi 2014). This research context builds upon traditional literature on technological change, where a firm's proximity to knowledge-intensive production environments may induce several important externalities that it can benefit from (Lööf and Nabavi 2014). The firm can for example benefit from interacting in a high-technology environment (Tilton 1971), or grow larger as it gains efficiency in specific activities (Chandler 1977). The firm can also invest in its own internal knowledge in order to acquire information that is externally available (Mowery 1983), which might positively affect both its innovations and its assimilation of others' discoveries (Griffith et al. 2003). In particular, we see an increased interest in empirical research on how firms' and regions' internal knowledge sources (e.g., internal human capital or R&D) conjunct with their external knowledge sources (e.g., skilled labor and R&D activities in related industries) interact with the output of economic agents representing firms, or the output of regions representing specific districts (Almeida and Phene 2012, Cantwell and Zhang 2012). In this latter context there are only a few quantitative studies available, and several gaps that need to be filled.

With these observations, I find it relevant to pose a general research question that encompasses the collection of works presented in this thesis: If knowledge can travel across space, then how are different knowledge types of firms and regions affected?

Knowledge can be embodied and stored in different forms. Imagine that knowledge is contained in physical goods that are put in a container in 'Location B'. As an alternative, imagine that knowledge is embodied in persons, or consider that it is codified in documentation stored by a firm or a research laboratory in 'Location C'. As an additional complication, assume that locations 'B' and 'C' are spread out across space, with locations in different municipalities, regions or countries. As a final step, imagine that i) the physical goods from 'Location B' are shipped to another distant location, which can be referred to as 'A', or that ii) the persons and documentation in 'Location C' become available for economic agents in 'Location A'. This thesis analyzes how knowledge, from locations such as 'B' and 'C', affect both the demand for, and the creation of, knowledge in 'Location A'.

The results presented in this thesis are particularly important for knowledge management and the way managers control the operations of their firms in terms of production organization, production costs, sourcing of factors of production, global competition and job tasks. Moreover, the results presented here are also essential for policy makers for the design of policies at all levels, from the EU to the very local level. At the EU level, the empirical results can be useful within the framework of the Lisbon Agenda and its successor the

EU2020, where the aim is to create a climate in Europe that stimulates innovation, competitiveness and economic growth. At the regional level, the shifts in location of production can affect growth and cause changes in the labor market. Thus, the empirical results presented here can benefit how governments design their future trade policies and future education and training policies. Finally, what is accomplished in this thesis is also important for researchers since new research challenges are generated. Each individual thesis paper comes with some suggestions for possible extensions of the empirical research presented here.

Table 1 presents the terminology used in the introductory part of the thesis. The remainder of this introduction outlines the theoretical background and the motivation for the research questions examined in this thesis. Section 2 deals with the theory of economic networks. The section also reviews the literature of knowledge networks and innovation networks, and ends with a presentation of the various knowledge types analyzed in the thesis. Section 3 presents the theory of location and trade. It also incorporates descriptive statistics on international trade and investment of Sweden. The properties of data utilized in the thesis are discussed in Section 4. Finally, Section 5 presents the motivation, purpose, contribution and the main findings in Papers 1 through 4. In addition, the section also suggests future research issues.

Papers 1 and 2 address how the knowledge composition of the labor force in Swedish manufacturing firms is impacted by changes in imported goods. Paper 1 analyzes imports of capital and intermediate goods and how their quality influences labor demand in different firm size categories. In Paper 2 the analysis is directed toward an examination of how offshoring of intermediate goods affects different occupations. The technology-specific content of the offshored intermediate goods is emphasized. Moreover, Papers 3 and 4 address how knowledge embodied in exported goods and codified knowledge in patents are affected by changes in new routines. Paper 3 analyzes how firms' knowledge absorption capacity affects the development, adoption and introduction of new export products among Swedish manufacturing firms. Finally, the focus in Paper 4 is on innovations measured in terms of local patents production in European regions. In this paper, we analyze how the local patents production in a European region benefits both from local R&D inputs in its own region and from spillovers of R&D inputs in other European regions.

Table 1 Definitions of words and phrases used in the introduction of the thesis.

Word, phrase	Definition
Node	A firm or an economic agent operating in a firm
Economic link	A recurrent relationship formed by two or more nodes to channel transactions
Economic network	A set of nodes connected by economic links (e.g., a firm with many affiliates)
Intra-firm network	All nodes with economic links in the economic network belong to the same ownership
Inter-firm network	Nodes with economic links in the economic network belong to different ownership
Knowledge network	The interaction among knowledge workers (e.g., scientists), universities and firms
Innovation network	An economic network designed to develop, nurse, protect and renew its tacit and codified know-how
Innovation	In this thesis: an introduction of a product that is new to the firm, or in the form of protecting new technical solutions via patenting of the ownership right of the new ideas
Knowledge types:	1. Embodied in people (e.g., human capital in the form of skills acquired through learning by doing, training and meetings)
	2. Embodied in goods, processes and routines (e.g., hardware, software and job tasks)
	3. Disembodied in a licensing agreement (e.g., by international outsourcing) and patents
	4. Know-how about how to carry out R&D (e.g., as R&D spillovers from one firm (or region) to another
Insourcing	A firm's licensing contract with another firm in its own company group, domestically
Outsourcing	A firm's licensing contract with another firm outside its own company group, domestically
International insourcing	A firm's licensing contract with another firm in its own company group, internationally
International outsourcing	A firm's licensing contract with another firm outside its own company group, internationally
Make	Refers to insourcing and international insourcing
Buy	Refers to outsourcing and international outsourcing
Offshoring	Refers to international insourcing and international outsourcing combined

2 Economic Networks

Economic networks theory raises many interesting and distinct questions that are important for the subsequent analysis in this thesis. These questions relate to: What is a node? What types of nodes are there? What is a link? What types of links are there? What is a network? What types of networks are there? This section reflects the standpoint of the literature on economic networks. Economic networks theory sets the foundation to why firms exist and can be expanded to encompass knowledge networks and innovation networks, as well as different types of knowledge examined in empirical research and in this thesis.

2.1 Nodes, Economic Links and Economic Contracts

Nodes connected by links are by many researchers seen as the basic elements that constitute a specific network (Johansson 1993, Johansson 1995, Cappelin 2003, Karlsson et al. 2005). If the focus is on economic networks at the micro level, one can distinguish two types of nodes: namely firms and economic agents operating in firms (Karlsson et al. 2005).[1] Each node has a specific function that not only depends on its relationship with other nodes, but also on its position in the network as a whole (Cappelin 2003). Nodes in terms of buying nodes and selling nodes demonstrate how transactions are channeled within the economic network. The relationship formed between a buying node and a selling node can thus be referred to as a link (Johansson 1993).

To understand the formation of economic networks and how economic links are established, it is highly important to address the theories on transaction costs and economic contracts. A buying node and a selling node that form a link should be analyzed as a capital object (e.g., a lasting relationship that consumes both time and costs), and thus has sunk cost characteristics (Johansson 1993). An economic network brings structure into how nodes interact in the market economy. Such a structure can be explained in terms of a contractual agreement formed between the buyer and the seller. A transfer of property rights between nodes generate transaction costs (Coase 1937, 1992). These costs are divided by Arrow (1971) into exclusion costs and interaction costs (e.g., information exchange costs, negotiation costs, contract formation costs, monitoring costs, contract enforcement costs and search costs).

If both transaction parties invest in a link with recurrent deliveries they have established an economic link. A lasting economic link between the buyer and the seller relies upon a long-term contract that acts to reduce the transaction costs. In this context, a lasting economic link has a scale advantage as repeated transactions are processed in accordance with the long-term contract (Johansson 1993, 1995). With an established link, the buyer and seller link can also survive with an explicit contract that is incomplete (Johansson 1995).

Williamson (1979) notes that transaction costs are grounded in the fact that organizational rationality is bounded to some limit, which in turn resides in that all complex contracts become incomplete. However, Williamson emphasizes that transaction costs can be removed or at least be minimized if the firm organizes the contracts internally through vertical integration or by implicit contracts. Moreover, Karlsson et al. (2005) argue that complete contracts[2] are rare and too costly to formulate. In addition, networks dealing with incomplete

[1] A node can also consist of economic agents operating within organizations that engage in innovative activities, such as universities or research institutes (see, e.g., Ejermo and Karlsson (2006)).

[2] A complete contract is of explicit form and specifies the obligations of each interacting economic agent. As such, complete contracts require vast resources to establish.

contracts must be supported by a number of other factors such as mutual economic commitment, ownership relations, various forms of social ties, mutual trust and relations based on confidence. These factors are also stressed by Rauch (1999, 2001) to be important for firms as they engage in international trade. Kilkenny and Fuller-Love (2014) use social network analysis in order to better understand economic networks. They suggest that the structure of the network affects the market power of its members.

Institutions, both formal and informal, play an important role for economic networks to function, since they organize the economic links between the various nodes, and thus also aim at reducing the transaction costs between them.[3] This is the foundation of why firms exist and how incentives are formed to establish economic links through lasting contracts.

2.2 Knowledge Networks

'Knowledge networks' is a concept coined by Beckmann (1993, 1994: p. 234) and is defined as "… *the interaction among scientists*." A knowledge network can be modelled as a node in an economic network. The knowledge network thus refers to a specific node of knowledge handlers in an economic network. (Karlsson et al. 2014). The concept has been commonly adopted by Swedish economists to be included in their economic models when focusing on high-technology industries (Beckmann 1995).

Economic models of knowledge networks incorporate both transportation networks and telecommunication networks, since the exchanges of knowledge in a knowledge network are assumed to take place via meetings of individuals that make use of infrastructure networks (Kobayashi 1995, Nagurney 2011). An additional assumption in a knowledge network model is that there are two types of workers in a firm, 'knowledge workers' and 'goods workers'. In line with Nagurney (2011: pp. 264-266), firm i's production of q_i units is given by

$$q_i = g_i(D_i, G) f_i(K_i, L_i) \,, \tag{1}$$

where the knowledge component $g_i(D_i, G)$ is a function of the information systems capacity (D_i) and G is a vector of the amount of 'knowledge workers' specified at each node such that $G = \{G_i\}$.[4] Equation (1) also incorporates a goods component $f_i(K_i, L_i)$, which is a function of firm i's physical capital in terms of machinery equipment (K_i) and its amount of 'goods workers' (L_i). The

[3] In this context, formal institutions refer to rules written by a third party, whereas informal institutions are social capital or social interactions (see, e.g., North (1990)).

[4] The knowledge networks models are rather flexible as various knowledge measures, such as accessibility to universities or accessibility to knowledge-intensive business services (KIBS), can easily be adapted in the production function presented in Equation (1).

maximization problem for firm i in the competition for 'knowledge workers' follows from its objective function $(u_i(D_i, G, K_i, L_i))$, which is composed by firm i's revenues less its cost of inputs according to

$$u_i(D_i, G, K_i, L_i) = p_i g(D_i, G) f(K_i, L_i) - r_i K_i - w_i L_i - \theta_i D_i - \eta D_i - \omega G_i) \,, \qquad (2)$$

where p_i is the price of the good produced in firm i. Moreover, note that the rent for information systems (η) and the wage rate for 'knowledge workers' (ω) in Equation (2) are assumed to be uniform. The maximization of $u_i(D_i, G, K_i, L_i)$ for firm i is then subject to non-negative inputs of D_i, G_i, K_i and L_i that it must decide on to reach a knowledge network equilibrium.

A firm can have various forms of internal nodes existing in its economic network. The firm can for example have internal and external nodes for communication, and for production, as well as specific nodes that establish economic links for coordination of resource flows (Karlsson et al. 2005). Economic links that are formed between nodes serve as channels for how knowledge diffuses and becomes exchanged within the economic network (Karlsson et al. 2014). As such, knowledge transfers may occur within a firm or between firms if they belong to the same economic network. Hence, if nodes in an economic network belong to the same company group, this economic network can be referred to as an intra-firm network. Nodes in an economic network that belong to different company groups constitute an inter-firm network.

Because intra-firm networks and inter-firm networks can operate both domestically and internationally, knowledge can diffuse through economic links coordinated between countries. Karlsson et al. (2005: p. 7) stress the importance of knowledge networks, such as intra-firm networks and inter-firm networks, as they generate innovations which strongly affect the technological dynamics in the international competition.

2.3 Innovation Networks

Economic networks need to develop and nurse their tacit and codified know-how. They need also to protect their tacit and codified know-how from other competing firms. Economic networks that are slow to respond to competitors' developments in the production environment and in the technological progress will lack the ability to sense the opportunities in the market over time.[5] This subsection refers to these developments in the firm as "innovation networks" and will deal with questions such as: How is an innovation regarded in the present thesis? What is innovativeness? How are innovations generated and assessed in firms? How are they modelled?

[5] A more detailed outline is conferred in Teece (2000) and in Karlsson and Manduchi (2001).

In this thesis, an innovation can take on a physical form, such as when an economic network introduces a product that is new to itself and is intended for sales in foreign markets. An innovation is also regarded in the form of new technical solutions that need to be protected via patenting of the ownership right to the new idea.[6]

Rogers and Shoemaker (1971: p. 27) define innovativeness as: "… *the degree to which a firm is relatively earlier in adopting an innovation than other members of its system*." By 'relatively earlier', Rogers and Shoemaker refer to the actual time of adoption, thus indicating the importance of being first with a new idea. Lieberman and Montgomery (1988) suggest that the leadership in an innovation (or technological idea) arises from learning or experience, and induces a firm to gain a first-mover advantage in the market. Moreover, Karlsson and Warda (2014) note the importance of established contacts between agents, such as producers, customers, suppliers, universities and research institutes for innovations to be created and for new ideas to be circulated within the knowledge network.

Innovations can be both demand-driven and supply-driven in the economic network. For example, Jovanovic and Rob (1987) describe demand-driven innovation processes that adhere to a top-down approach. To see this, the innovation in a top-down context is initiated by the production managers that are directly interacting with the requests from business customers, and the solution is provided by the R&D workers. In contrast, a supply-driven innovation is generated from a bottom-up approach. In this context, the nature of the innovation is determined by the R&D workers, whereas the production managers take on a more passive role. Kamien and Schwartz (1982), however, claim that the interaction of technological opportunity and economic opportunity is primarily important for innovations to be generated in economic networks.

The assessment of an innovation's viability can be separated into different stages. For example, an innovation with properties that are very similar to those of an existing product and process can be viewed as an incremental change. If the innovation results in a completely new product, yet uses a near to existing process, the innovation is seen as a breakthrough. A breakthrough would also be the case if the innovation generates a completely new process to produce a product that already exists. The game changer (such as a radical innovation) stems from a disruptive innovation meaning that both the product and the process are completely new to the innovation network. In the latter case, the innovation network needs to work with new technologies, which require a completely different set of skills compared to an innovation network that does incremental product and process innovation (see, e.g., Slater et al. (2013)).

Schumpeter (1934: pp. 65-66) suggests that innovations in the economic system do not come spontaneously from consumers. It is rather the producer

[6] These types of innovations are analyzed in Paper 3 and Paper 4.

that initiates the economic change and consumers have to be stimulated to desire new goods or existing goods with new attributes. To produce something, a new good of some sort, requires a combination of materials and labor. To produce other or same goods, by different methods, implies combining these inputs in a different way. New combinations emerge from old combinations via a continuous adjustment, thus indicating that the firm experiences economic change, and perhaps growth. If such progress is not the case, the new combinations will appear discontinuously. According to Schumpeter, it is in this disruptive process that birth is given to development, which is driven by the carrying out of new innovative combinations. Hence, the process to reach a new innovative combination begins with introducing something new, e.g., a new good, which consumers are not familiar with yet. Secondly, new goods require new processes or methods of production. Third, new goods and new processes are in need of new markets, irrespective of whether or not the market has existed before. Fourth, the former three stages of innovativeness require new supply sources, either to be conquered from already existing sources, or to be created for further stimulation of the new combination. Finally, when the new combination is achieved, the intent of the last development stage is to carry out the organizational change or the production option needed in order to create a market advantage or to break down an existing one.

von Hippel (1978) stresses the role of the customer to be important for how ideas can generate new industrial products (which is a different approach compared to Schumpeter (1934)). Nelson and Winter (1977, 1982) note that innovations and market structures are driven by market selection and the nature of technology. Kamien and Schwartz (1982) suggest that the rate of innovation is based on firm size, and monopoly power (i.e., a Schumpeterian view on innovation). Malerba and Orsenigo (1993) argue that firms' innovative processes depend on a combination of opportunity and appropriability, cumulativeness of technological knowledge, and the characteristics of the relevant knowledge base. Audretsch (1995) points out that opportunity and appropriability are the most important conditions that affect market structures and innovations.

In recent empirical works, Malerba (2004) emphasizes the importance of knowledge and technologies, actors and networks, as well as the role of institutions. Andersson and Karlsson (2006) recognize the importance of national and regional innovation systems, which include firms' collaboration and interaction with actors such as customers, producers, subcontractors, consultants, public organizations, research institutes and universities. Cainelli and De Liso (2005) and Cainelli (2008) find product innovation as a key factor explaining firms' productivity. Hoekman et al. (2008) and Ponds et al. (2010) find that universities and collaboration networks in close proximity have a significant positive impact on the regional innovative activity (measured in the

form of patents).[7] Rodríguez-Pose and Comptour (2011) highlight the importance of clusters and a good social filter (in terms of education and skills, use of human resources, demographic dynamism, risk-taking, and sectoral specialization) for innovation growth. Mihalache et al. (2012) observe that firms' innovativeness (in terms of revenues attributable to new products and services) enhances as primary functions such as R&D, production, and engineering become relocated across national borders. A reason for this observation may be that firms gain access to valuable tangible and intangible resources that either augment or complement firms' existing resource stock. Tavassoli (2014) quantitatively examines the determinants and effects of innovation on firms' export performance by separating between innovation input and innovation output. Innovation output is observed to significantly improve firms' export behavior, whereas innovation input has a neutral effect on the export behavior.

2.4 Types of Knowledge in Empirical Research

Economic contracts form the foundation for why economic networks exist. An economic network has various internal nodes that establish economic links with other nodes in order to coordinate the resource flows within the economic network. Resource flows contain both knowledge components and goods components that together constitute the supplies and demands of a knowledge network. In a knowledge network, the innovation output depends on what is put into the production and the costs of such inputs, be these related to new labor routines or material used in production. In this subsection, the intention is to elaborate on how the types of knowledge have been outlined in empirical research. Related questions include: What types of knowledge are there? What is embodied knowledge? What is disembodied knowledge? What types of knowledge have been applied in empirical research that are relevant for this thesis? How is knowledge examined in this thesis?

There are various ways to examine the role of knowledge in empirical research, as well as many alternative types of knowledge.[8] The relevant approach in this thesis is to analyze how knowledge contained in traded goods influences firms' labor demand, and how knowledge contained in new routines affects the innovative performance in firms and regions. Thus, the starting point of investigating these phenomena in this thesis is through a production function (Schumpeter 1942, Arrow 1962, Chambers 1988, Romer 1990, Grossman and Helpman 1991, Hamermesh 1993), and typically relate to how

[7] Ács et al. (1994) find substantial evidence that R&D spillovers into innovative activity are facilitated by the geographical proximity of universities and research laboratories.

[8] See, e.g., Andersson and Beckmann (2009) for an extensive review of various models that examine knowledge. In addition, Machlup (1962) provides a list on alternative types of knowledge that can be examined in empirical research.

augmented human capital in production increases the productivity of workers (Lucas 1988), or how increased R&D capital in production increases the capacity to innovate (Romer 1990). In this sense, knowledge can be embodied:

1. in people as human capital in the form of skills acquired through learning by doing, training and meetings, by reading and understanding documents and books, by obtaining experience or by an education (Andersson and Beckmann 2009);

2. in goods and R&D capital in the form of technical solutions (e.g., hardware and software), related to specific machinery or to certain production routines and processes (Romer 1990, Grossman and Helpman 1991, Johansson and Lööf 2014);

or knowledge can be disembodied:

3. in licensing agreements, e.g., by outsourcing the production of final goods and/or intermediate goods to a subcontractor (Cassiman and Veugelers 2000).

The first and second form of embodied knowledge can be referred to as distinct channels that diffuse knowledge. Embodied knowledge in people incorporates knowledge in the exchange of ideas when economic agents interact (e.g., through formal and informal meetings with input suppliers of engineering solutions or other knowledge-intensive business services), as well as market transactions that represent intentional knowledge transfers (Johansson 2005). In this sense, Karlsson and Gråsjö (2014) argue that it is important to separate the knowledge of economic agents (i.e., firms and organizations) in terms of know-how and know-why. On the one hand, know-how is embodied in people or economic agents in the form of expertise, skills, and practical attainment that can be present without codification. As know-how, in some cases, is too difficult or too costly to codify, it is a form of tacit knowledge. On the other hand, know-why represents a scientifically accepted explanation that can be codified, yet requires specific skills and training to be understood. As such, knowledge embodied in people (i.e., human capital) is a combination of both know-how and know-why (Karlsson and Gråsjö 2014). The exchange of ideas when economic agents interact can be related to the human capital theory reflected in Lucas (1988). In this context, individuals have knowledge characteristics that they cannot be separated from. Human capital can thus diffuse given that individuals are mobile within a location or a firm, or are mobile between locations or firms. According to Lucas (1988), positive externalities in the firm arise from both the individual's human capital by increasing its own productivity and from the average level of human capital in the firm by increasing the efficiency of all the production factors. Individuals with large human capital can diffuse knowledge that benefits their co-workers with low human capital via learning and training activities. Other productivity

gains from human capital can include: improved ability to de-codify market transactions, such as costs associated with the coordination of activities within the firm (Gereffi et al. 2005), increased capacity of mangers to handle information (Backman 2013), better capacity to absorb external knowledge (Cohen and Levinthal 1990) that can benefit firms by making imitation more easily adopted (Ballot et al. 2001).

Knowledge embodied in machinery can be referred to as unintentional knowledge spillovers that are obtained when equipment and other goods are exchanged through diffusing technological know-how and know-why that is embodied in traded goods (Karlsson and Gråsjö 2014). For example, the unintentional knowledge spillovers are obtained when an advanced machine is bought, disassembled on its parts, followed by an in-depth examination of the parts, to later become re-assembled with additional improvements. Another example of unintentional knowledge spillovers refers to a scenario in which the seller unintentionally reveals information to the buyer, which the buyer intercepts and implements for commercial gains (Johansson 2005, Johansson 2010). Moreover, human capital can also be examined in endogenous growth models initiated by Romer (1986, 1990, 1993), where R&D investments induce new ideas that transform into new goods and new processes. The general message from Romer's growth models is that new goods and processes are more likely to be developed in firms and/or regions with a greater amount of R&D knowledge than in the average firm and/or region.

The third form of disembodied knowledge usually follows from an intentional strategy followed by the firm, for example by international outsourcing. There are several underlying reasons for establishing a licensing agreement by international outsourcing.[9] One motive that often underpins the international sourcing strategy of the firm follows from a cost minimization of certain processes related to production, such as simple assembly (van Winden et al. 2011) or activities related to research, science and innovation (Veugelers 2010). The literature in this field that combines the theories of location, production, and international trade in inputs stresses the importance of knowledge diffusion in the exchange of goods between countries (Jones 2000, Deardorff 2001, Eaton and Kortum 2001, 2002, 2007, Feenstra 2010).

To see this, take Audi AG as an example and its production of the car model Audi TT. The design of the Audi TT is sketched in Ingolstadt, Germany. The Audi TT platform is developed and produced by Volkswagen AG.[10] The chassis, the engine and the components of the car model are produced and assembled in Györ, Hungary. Additional components are imported from Changchun, China. Finally, the body paint, safety check and finish are

[9] International outsourcing will be further elaborated upon in Subsection 3.2.1.

[10] It is unclear where the car platform is produced, however, Volkswagen AG produces passenger cars using this car platform in Wolfsburg (Germany), São José dos Pinhuis (Brazil), Brussels (Belgium), Bratislava (Slovakia), Uitenhage (South Africa), Changchun (China), Jakarta (Indonesia) and Solomonovo (Ukraine).

performed at the main production site in Ingolstadt. After this chain of activities, the Audi TT can be sold in the European and other markets. Thus, Audi AG's coordination of flows to diffuse the knowledge contained in each activity of producing the Audi TT is highly dependent on its production efficiency, information about the market (i.e., the cost structure and the demand structure), as well as its knowledge on how to move the intermediate activities from one point to another (i.e., the logistics and distribution of each activity).

Saggi (2002) notes that multinational firms, such as Audi AG, act as potential spillover channels of knowledge i) by introducing new technologies that local firms absorb, ii) by labor mobility among trained staff in multinational firms that become employed in the local firms, and iii) by vertical linkages between the multinational and the local firms, which simplifies the transfer of new technologies and knowledge. Moreover, Feenstra (2010) suggests that components trade (or intermediate goods trade) can explain ongoing changes in the labor market. Such changes in the labor market include differences in the relative wage structure between non-production and production workers and shifts in firms' demand for labor. Empirical works have confirmed that international trade in components (or call it offshoring) has a significant effect on shifts in the skill structure of labor. For example, Berman et al. (1994), Feenstra and Hanson (1996b), Strauss-Kahn (2004), Hijzen et al. (2005), and Görg et al. (2013) find that offshoring has shifted the demand from low-skilled to high-skilled labor, whereas Foster-McGregor et al. (2013) observe a negative effect on both low-skilled and high-skilled labor.

Another way to examine the role of unintended spillovers from knowledge inputs is through adopting a knowledge production function framework. In this literature, the epic work of Griliches (1979) can be referenced as a starting point to analyze how R&D investment generates and diffuses knowledge into innovative activities. In this context, knowledge can be embodied:

4. in R&D (e.g., in terms of total effect of R&D expenditure, or as R&D expenditure per capita or per worker, or as private R&D and public R&D expenditure, or as R&D share of GDP or GRP), in the form of innovative activities related to patents and publication citations, technology licensing or total factor productivity (Karlsson et al. 2013).

The fourth form of embodied knowledge can be referred to as a distinct form of knowledge creation and diffusion. Later adaptations of Griliches work include the development of the knowledge production function into a geographical dimension in Jaffe (1989), and into a spatial dependence framework in Anselin (2003). A great emphasis in these frameworks is put on science's role for industries, since an industry network usually incorporates knowledge channels that are linked to universities and research institutes (Ejermo and Karlsson 2006). In empirical research, a common approach has been to model the 'geography of innovation', describing how the knowledge

generation of firms is influenced by the research and innovation efforts of other firms in order to determine the influence of proximity on the knowledge output (Karlsson et al. 2013). For example, Botazzi and Peri (2003) estimate a knowledge production function of innovation for European regions using patent and R&D data by weighting for distance. They observe that the spillover effect of knowledge (measured in terms of patents) is large in the local region, however, the spillover from neighboring regions is rather small. In another study, Hauser et al. (2008) find that the spatial location of R&D expenditure and human capital has a significant effect on patent applications and hence drives knowledge to spill over.

2.4.1 Types of Knowledge in the Thesis

This thesis adopts knowledge of all four types in Subsection 2.4 in its analysis. Table 2 presents an overview of the adoption of the types of knowledge in Papers 1 through 4.

In Paper 1, the firm's labor demand depends on the quality of the imported inputs that are plugged into its production function. As such, the knowledge input is embodied in imports, through capital goods (e.g., machinery equipment) and intermediate goods (e.g., components, semi-finished goods) of different qualities as these enter the firm's production function. The knowledge output is embodied in people and takes the form of human capital, which is measured by the education length of labor. Paper 2 narrows down the focus on imports' role in production by examining how the cost shares of different occupations are affected by international outsourcing of intermediate goods of different technologies. Thus, Paper 2 uses a similar knowledge input as in Paper 1; however, it focuses on intermediate goods only, which are distinguished by technological content. Different from Paper 1, the knowledge output in Paper 2 is embodied in certain production routines and processes in the firm through occupations and job tasks. Note that a licensing agreement, such as international outsourcing (which is somewhat the underlying theme in Papers 1 and 2), can also be seen as form of acquiring of knowledge that is disembodied.

Human capital of employees, accessibility to KIBS employment, and conjunction of human capital and accessibility to KIBS employment represent the knowledge input in Paper 3. Here, innovations, in terms of new export products, depend on the firm's internal knowledge intensity, as well as on its external knowledge potential. Thus, the knowledge output in Paper 3 follows from the absorption of knowledge, both internally and externally, in the firm's development of exports products.

Finally, the knowledge embodied in R&D is analyzed in Paper 4 as a knowledge output through patents production in the local region. The knowledge output in this case also takes the form of spillovers on patents production in the local region. Moreover, the knowledge input in Paper 4 is

measured in terms of un-weighed and distance-weighed R&D expenditure in the local region and in the neighboring regions.

Table 2 Adoption of knowledge types in Papers 1 through 4.

Paper	Theme	Knowledge input		Knowledge output	
		Name (unit of analysis)	Type	Name (unit of analysis)	Type
1	Imports and labor demand	Imported inputs of different quality content, such as capital and intermediate goods (firm)	2 / 3	Human capital in terms of education of labor (firm)	1
2	Offshoring, occupations and job tasks	Imported inputs of different technological content, such as intermediate goods (firm)	2 / 3	Human capital in terms of labor occupations and job tasks (firm)	2
3	Knowledge absorption in the development of export products	- Human capital (firm), - Accessibility to KIBS employment (local and intra-regional), - Conjunction of human capital and accessibility to KIBS employment	1 / 4	Innovations in terms of new export products (firm)	2
4	Knowledge spillovers on local patent production	Un-weighted and distance-weighted R&D expenditure (intra-regional and extra-regional)	4	- Innovations in terms of local patents production (intra-regional) - Innovations in terms of spillovers on local patent production (intra-regional)	2

A critical role in an economic network is played by the knowledge network, through which transfer, diffusion, and spillovers of knowledge takes place (Karlsson et al. 2014). This knowledge network, be it a firm or a region that relies heavily upon its knowledge function, has an important role in the present thesis for how knowledge channels can be exploited across space. This exploitation of knowledge is channeled, either through international labor divisions via imported goods, or through the absorption of external knowledge potentials in terms of developing and improving the knowledge and ideas of people via R&D and scientific research. The division of labor, once in time thought of as fixed, has with the changing global scene in current time become highly international. As such, the following section gives a general background on how the theoretical frameworks in research on location and trade have changed over time.

3 Location and Trade

An important follow-up question on the previous section regards what factors motivate the interaction of location and trade in economic networks. The following subsection outlines the theories on the interaction of location and trade that have developed historically over time. Subsection 3.2 reviews the

theories on location and trade in inputs and components, and rounds off by addressing production fragmentation in a context of make and buy decisions. Subsection 3.3 focuses on location and trade in outputs by highlighting innovations in exports. Subsection 3.4 closes Section 3 by mapping the general trade and investment patterns of Sweden and Swedish manufacturing.

3.1 Location and Trade: A Historical Perspective

The theoretical frameworks for conducting research on location and trade have broadly evolved over time. Ricardo (1817) developed the understanding of Adam Smith's (1776) theories on the advantages of the division of labor. The direction of trade was suggested, by Ricardo, to depend on a comparison of relative prices in autarky. The differences in technology between two countries determined the basis for gains in trade in terms of comparative advantages. The focus of Ricardo's theory of comparative advantage was on a single factor of production in the form of labor, which was assumed to be immobile between countries.

The Heckscher-Ohlin (H-O) theorem published in Ohlin (1933), re-specified the Ricardian model as it explained the gains from trade to be based on the same technological attributes across countries, but instead ascribed the comparative advantages to the cost disparities arising from differences in factor prices across countries.[11] According to the H-O theorem, a country would export (import) the good that uses its relatively abundant factor intensively (less intensively) in production. Leontief (1953), however, empirically tested the H-O hypothesis for the capital abundant US economy and found that the US economy was exporting labor-intensive goods and importing capital-intensive goods. Leontief's findings have been widely criticized by many economists as his empirical testing lacked the inclusion of human capital. In this critique, economists have argued that the US economy has a greater advantage in human capital through high-skilled labor, rather than being a mere capital abundant economy. Although making an important contribution to trade theory, the Ricardian model and the H-O theorem could only explain the gains from trade in final goods with immobile factors of production between countries. Thus,

[11] Although Bertil Ohlin wrote the book explaining the theory in 1933, Eli Heckscher was also credited for the model because of his earlier work on the topic in Heckscher (1919). Stolper and Samuelsson (1941) extended the Heckscher-Ohlin model by adding on international factor rewards in response to changes in the output price (i.e., the Stolper-Samuelson theorem). Later, Samuelson (1953) formalized a general equilibrium model by also incorporating the effects on production of exogenous change in domestic factor supplies (i.e., the Rybczynski theorem). This extension of the H-O theorem is referred to as the Heckscher-Ohlin-Samuelson (H-O-S) theorem, or the factor abundance theory that explains the patterns of trade and factor price equalization.

the theoretical frameworks at this point in time still favored static factor dynamics in the location aspect.

In the 1960s, more firms began to explore their potential to establish international production (see, e.g., Wilkins (1974) for a review). This development gave rise to a ramification in the theoretical frameworks for research on trade that highlighted location and various motives for why firms operate internationally (Hymer 1960), not least by highlighting technical change (Posner 1961). The institutional approach in Vernon (1966) and in Hirsch (1967) to explain differences in production structures, knowledge-related activities of labor and gains from trade between countries solved some of the question marks the H-O theorem brought in Leontief (1953). They based the analysis on developments in the life cycle of a product. The early stages in the product life cycle, such as product and process development, would commonly become executed from the domestic establishment to keep sub-contractors and competitors in proximity in order to receive the necessary feedback and flexibility to better develop the product's physical form. At later stages, when the product's demand would become more standardized, mass production especially involving simple assembly processes, would be adapted in foreign markets at different locations. The development at the later stage defined the conditions for labor saving and high income elasticity that often characterized a multinational firm at its domestic establishment.

Another trend that was intensely analyzed at this period was international trade flows channeled within the same industry. Intra-industry trade, as this trend was referred to, was first acknowledged through the work of Balassa (1966), and was later analyzed in Grubel and Lloyd (1971), followed by Lall (1978), and many other researchers. Balassa (1966) found that the European Economic Community (EEC) imposed a substantial threat to US exports. In addition, low trade barriers in the EEC made its industrial countries predominantly devoted to intra-industry trade. A majority of previous research in this context has shown that intra-industry re-allocations have a significant effect on both re-location of production and improved firm productivity.[12]

In line with the empirical research on intra-industry trade, a first glance on new trade theory could be depicted in Krugman (1979). In this work, Krugman noted the importance of internal economies of scale to show that trade and gains from trade occur between countries with identical tastes, technology and factor endowments. Krugman's main conclusion was that trade not only needs to be due to differences in technology or factor endowments, rather that trade can be a way of extending the market by exploiting scale economies. Furthermore, the general equilibrium model presented in Krugman (1979) was extended in Krugman (1980) to also include transportation costs. Almost a decade later, the previous work of Krugman converged into a geographical

[12] See, e.g., Clerides et al. (1998), Bernard and Jensen (1999), Aw et al. (2000), and Melitz (2003).

perspective in Krugman (1991). This work of Krugman gave a direct linkage between geography and trade, and became known as new economic geography. Here, the focus was set on 'home market' effects due to pecuniary externalities induced by markets characterized by monopolistic competition and 'a taste for variety'. The model presented in Krugman (1991) could endogenously solve for how a country differentiates industries into core and periphery. Again, Krugman's model focused on economies of scale in combination with minimized transportation costs. The core-periphery pattern of an industry's location was drawn to where its demand is larger, however, the location of the demand depended on the distribution of industries. Thus, Krugman's model incorporated 'agglomeration effects' that depended on transportation and trade costs, increasing returns from economies of scale, as well as on the relative price of labor through factor price differences. As such, trade theory was pushed from having a static view on factor dynamics and location, towards trade theory with a dynamic view on location by incorporating factor dynamics after trade.

However, many economists have touched on the fact that the importance of the interaction of location and trade was written in ink already in Ohlin (1933). Krugman himself has noted that this is indeed the case, but that Ohlin was missing out on a number of insights needed to clarify his theories on location and trade relating to i) a distinctiveness on the nature of imperfect competition, ii) a distinction between equilibria and optima, and iii) ideas of qualitative and discontinuous change.

3.2 Location and Trade in Inputs and Components

More recent theoretical frameworks in location and trade theory have diverted the focus on the gains from trade in final goods into gains from trade in inputs and/or components by combining the theories on location, trade and production (see, e.g., Jones (2000), Deardorff (2001) and Feenstra (2010)). As such, these frameworks depart from the historical static view on factor dynamics in the location aspect. Moreover, the elements of Ricardo and Heckscher-Ohlin still have a substantial role in the theory of input and components trade (Arndt 1998a, Jones 2000). Another important feature in this field of research is that the theoretical frameworks invite human capital to enter the models.

According to Arndt (1998a, 1998b) production fragmentation can improve both the trade and welfare of a country.[13] For example, Arndt (1998a, 1998b) notes that a country's comparative advantage in final goods is not only a function of its internal endowments, but also of its access to imported parts and components. Arndt's framework shows that offshore production by labor-intensive import-competing industries in high-income countries strengthens the

[13] See also Dluhosch (2006) for how fragmentation can induce country gains in welfare.

industries by expanding the employment and output, thus causing wages to rise relative to capital rents. Another interesting analysis in Arndt (1998a) is the two-way relationship between components trade and human capital. Here, components trade causes human capital accumulation and thus endogenizes economic growth and development. Human capital accumulation, on the other hand, can affect the optimal path of components trade.

In a framework of 'fragmentation',[14] Jones and Kierzkowski (2001) introduce a model where 'fragmentation' makes it possible to trade with inputs, which induces a re-alignment of the production patterns among countries. The strength of the fragmentation model is that it captures the differences in both technology and factor productivity, and in this way incorporates the Ricardian, the Heckscher-Ohlin elements. The model assigns a key role to increasing returns to scale, and to service links in the various production segments. By highlighting the importance of increasing returns, the fragmentation model of Ronald Jones and Henryk Kierzkowski also considers the Krugman element spawned in new trade theory. Moreover, an argument for assigning a key role to service links in the model is that they play an important role in connecting the separate production locations and the specialization gains from components trade. The greater costs of having more service links to cross national borders[15] are offset by firms' lower marginal cost of producing. The recent advances in information and communications technology, and the deregulation of service activities worldwide have pushed the costs of service links downwards. As such, fragmentation helps explain the international input mobility observed in today's interaction of location and trade. The fragmentation model can be adapted for the capital input such that physical and human capital are analyzed in terms of skilled labor, whereas the labor input represents unskilled labor.

One main contribution of new trade theory is its integration of economies of scale and monopolistic competition (through product differentiation) to the existing literature on international trade models, and especially models that focus on trade in inputs and/or components. In this sense, new trade theory creates a direct linkage between international trade and multinational firms (McCann 2009). Many works with theoretical and empirical insights have been published within related issues. For example, advantages of vertical integration are analyzed in Aghion and Tirole (1997). Markusen (2002) conceptualizes a model for trade and pricing of knowledge assets in multinational firms. Görg et al. (2008) investigate the impact of international outsourcing on plant productivity. Andersson et al. (2013) examine how high-quality imported products diffuse technology into local industries. The various works of Feenstra and Hanson (1995, 1996a, 1996b, 1997, 1999) analyze how international outsourcing of firm activities affects the wage share of non-

[14] Jones and Kierzkowski (2001: p. 1) define the term 'fragmentation' as: "… *a splitting up of a previously integrated production process into two or more components, or fragments*."

[15] In this case, service links induce costs in terms of transportation, communication, planning and coordination.

production workers. This sequence of papers by Robert Feenstra and Gordon Hanson has served as a source of inspiration for subsequent applied research on international outsourcing's effect on the domestic wage inequality and job tasks (Hijzen et al. 2005, Egger and Egger 2006, Feenstra and Jensen 2012, Görg et al. 2013, Nilsson Hakkala et al. 2014), including Papers 1 and 2 presented in this thesis.

Feenstra and Hanson (1995) constructed a model that shows that trade in inputs and investment are an important part of explaining the changes in the relative wages structure and employment observed for the US and Mexico.[16] The Cobb-Douglas production function of output x in Feenstra and Hanson (1995) is reproduced here as

$$x(z) = A_i \left[min \left\{ \frac{L(z)}{a_L(z)}, \frac{H(z)}{a_H(z)} \right\} \right]^{\theta} [K(z)]^{1-\theta} , \quad (3)$$

where A_i is a constant that can differ between countries as indicated by subscript i. Input z uses $a_L(z)$ unskilled labor and $a_H(z)$ skilled labor, such that $a_H(z)/a_L(z)$ is increasing in z. Furthermore, $L(z)$ is the total usage of unskilled labor and $H(z)$ denotes the total usage of skilled labor. A unit of z requires capital, $K(z)$, in production such that it substitutes for labor. Finally, θ is the elasticity of the factors L, H and K used in production.

The associated minimum costs of one unit $x(z)$ in country i is given by

$$c(w_i, q_i, r_i; z) = B_i [w_i a_L(z) + q_i a_H(z)]^{\theta} r_i^{1-\theta} , \quad (4)$$

where $B_i \equiv \theta^{-\theta}(1-\theta)^{-(1-\theta)} A_i^{-1}$. w_i, q_i and r_i are factor prices for unskilled labor, skilled labor, and capital, respectively, in country i.

Country i's total factor demands for unskilled and skilled labor are obtained by differentiating Equation (4) with respect to factor prices and by integrating over all producing industries such that

$$L_i(q_i/w_i) = \int_0^{z^*} B_i \theta \left[\frac{r_i}{w_i a_L(z) + q_i a_H(z)} \right]^{1-\theta} a_L(z) x_i(z)\, dz , \quad (5)$$

$$H_i(q_i/w_i) = \int_0^{z^*} B_i \theta \left[\frac{r_i}{w_i a_L(z) + q_i a_H(z)} \right]^{1-\theta} a_H(z) x_i(z)\, dz , \quad (6)$$

where Equations (5) and (6) are the total factor demands for unskilled and skilled labor. The dividing point for which activities are allocated between countries is represented by z^*. The transfer of z from one country to another

[16] What initiates Feenstra and Hanson's (1995) model is an argument raised in Berman et al. (1994), where the latter note that the magnitude of international outsourcing (proxied as US imports of materials) is too small to account for any change in wages and employment in the US industries.

country is explained by Feenstra and Hanson (1995: p. 4) as a form of "endogenous technical change", which induces a shift in the factor intensities of production. In addition, they suggest that a way to model transfers of z is through imported intermediate and final goods that are used in the firm's production, or are sold under the firm's brand name.

According to Jones (2000), this latter stream of theoretical frameworks makes old research questions still stand strong; however, new research questions can be raised and old answers can be modified. It is within this younger field of literature that this thesis draws the majority of its research questions. The remaining part of this subsection reviews firms' production fragmentation based upon make and buy decisions.

3.2.1 Production Fragmentation: Make or Buy?

There are various ways for a manufacturing firm to strategically perform its production fragmented across space. It is important to note that the outline that follows below is in a context of manufacturing firms. Thus, firms in retail and wholesale are not the focus here. The questions that will be touched upon relate to: What type of production options are there for manufacturing firms? What is insourcing? What is outsourcing? What motives make firms to insource or outsource production fragments? What is offshoring and how is it defined in this thesis?

A manufacturing firm that wants to setup production can either establish production at a domestic location, or it may choose to establish production internationally. In line with Feenstra (2010), there are four ways for this firm to strategically choose the production option that fits its purpose best. Figure 1 depicts these four alternatives.

If the manufacturing firm chooses to only have domestic production, it can either establish domestic in-house production through an affiliated firm via domestic insourcing, or by contracting a domestic non-affiliated firm, i.e., domestic outsourcing. The first situation that refers to insourcing is a pure 'make' decision by the manufacturing firm. There are various reasons for firms to establish domestic in-house production. For example, domestic insourcing can be motivated by risk reduction and quality assurance (Turok 1993), or in order to protect tacit and codified know-how (Gereffi et al. 2005). Moreover, Gereffi et al. (2005) also stress that make decisions of firms are typically governed by difficulties in codifying transactions combined with low capabilities in the supply base. In such a case, the firm chooses to produce the components of interest itself.

The second option of domestic outsourcing deals with a situation in which the firm decides to 'buy' some production fragments from an external firm within the country's national borders. Domestic outsourcing can be induced by language similarity and historical ties to domestic networks, in particular to local domestic networks (Eriksson et al. 2008); efficiency and flexibility in

production through just-in-time deliveries (Reeves et al. 2010); proximity to domestic suppliers and markets (Jürgens and Krzywdzinski 2009); getting access to a specific production technology or human capital (van Winden et al. 2011); or to achieve a cost advantage through economies of scale (Kakabadse and Kakabadse 2002).

An alternative to domestic production is for the manufacturing firm to establish international production via investment or a licensing agreement. If the manufacturing firm chooses the abroad option, the production can be sourced to a foreign affiliate within its group, i.e., the manufacturing firm invests internationally by insourcing. The manufacturing firm can also establish a source to a foreign non-affiliated firm. In the latter case, the strategy followed by the manufacturing firm is to establish production abroad via a licensing agreement, e.g., by international outsourcing.

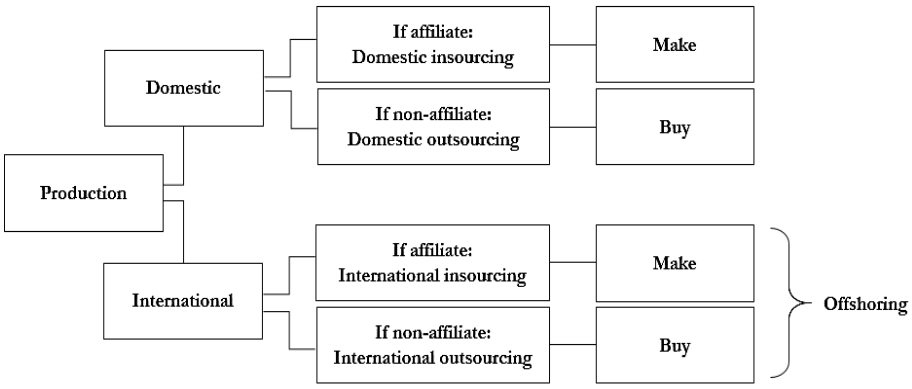

Figure 1 Production options of a manufacturing firm.

Source: Adapted from Feenstra (2010)

The following part is important in order to understand the terminology of the word 'offshoring' used in Papers 1 and 2. According to Feenstra (2010: p. 6), offshoring can either be measured in narrow terms, or in broad terms. The narrow offshoring measure describes what occurs when a firm sends a fragment of its production abroad, but keeps it in-house, thus indicating that the firm has become multinational (this is the upper segment of 'make' in Figure 1, when the production decision of the firm is international). In this way, offshoring is distinct from international outsourcing.

A more common way of measuring offshoring is when both the multinational strategy and the international outsourcing strategy are accounted for. The broader measurement of offshoring incorporates any transfer of

production overseas (this is both the upper segment of 'make' and the lower segment of 'buy' in Figure 1 when the production decision of the firm is international). In the remainder of this thesis, the use of 'offshoring' will be generic for 'international insourcing' and 'international outsourcing', when addressing manufacturing firms' production abroad (i.e., offshoring will be in terms of Feenstra's broad measurement).

Moreover, it should also be made clear that offshoring in Paper 2 in this thesis occurs when firms re-locate production of physical goods in terms of current inputs (e.g., semi-finished products such as components). Paper 1 deals with both current inputs and final goods (e.g., machinery equipment and other capital goods).

The literature provides many reasons for firms to engage in international production fragmentation. The most common reasons that appear in the literature are to minimize the costs of production, such as land rents and taxes (Yamashita 2010); to exploit the benefits of an international division of labor at lower wage costs (Kinkel and Maloca 2009); to gain technological competence by locating the production close to, or within an industrial cluster (van Winden et al. 2011); to access more lenient laws and regulations (Henderson et al. 2002); to gain proximity to global markets (Bhagwati et al. 2004); to exploit the benefits of free trade zones and other benefits in terms of low trade tariffs and quotas in trading blocs (OECD 2010); to follow the lead partner (Eriksson et al. 2008); to achieve economies of scale in production (Doh 2005); or, to access resources in production such as raw materials (Roza et al. 2011).

A transfer of input $\boldsymbol{z}$, e.g., initiated by a firm that engages in offshoring, can contain various levels of technologies that affect its production inputs of capital (human and physical) and labor somewhat differently.

Gereffi (1999a, 1999b) notes that each production fragment of a manufacturing firm has a specific input requirement for capital (human and physical) and labor in terms of input costs. In this sense, a manufacturing firm can have several cost conflicts to account for in its production landscape. Hence, it is these cost conflicts the manufacturing firm economizes upon when it makes its market transactions. For example, simple assembly tasks are usually associated with a lower cost per labor (in terms of wages), yet they induce a high total factor cost since such tasks are labor-intensive. On the other hand, some assembly tasks can be labor saving if the assembly instead is performed by a technological attribute, such as an automated machine. In this situation, a transfer of input $\boldsymbol{z}$ can be that the manufacturing firm imports advanced machinery to replace specific production fragments that are labor-intensive in its domestic production. However, after this transfer, the firm needs technicians who can operate such advanced machinery, or engineers who can maintain machinery. Moreover, since land resources are scarce and assembly is both space and attribute driven it often requires high rental costs for land and

machines. Thus, it might be more feasible for the manufacturing firm to transfer these production fragments to a low cost market.[17]

There are several indications why some firms decide to offshore some (or all) fragments of their production activities. The overall cost of an activity is one of many motives that leads to production fragmentation of the manufacturing firm. Manufacturing firms tend to be attracted to foreign regions characterized by cost advantages relative to their domestic markets (Bilbao-Ubillos 2010, van Winden et al. 2011). Human capital, physical capital and labor are input requirements in product and process development, and assembly, which in terms of composition are affected by the manufacturing firm's choice to engage in production fragmentation. Many contributions in empirical research have observed how the microeconomic structure of offshoring can have macroeconomic implications on for example the labor composition in countries, in specific sectors, and in certain industries (see, e.g., Feenstra (2010), Godart et al. (2013) and Warda (2014)).

3.3 Location and Trade in Outputs and Innovations

International economic theory on firms' export behavior stresses the importance of the location milieu in order for firms to augment their productivity, as well as their innovation pace (Grossman and Helpman 1991). In this sense, the information and knowledge available in the environment in which the firms are located impact positively on firms' export capacity (Malmberg et al. 2000, Chevassus-Lozza and Galliano 2003, Antonietti and Cainelli 2011, Cainelli et al. 2014).

The role of localization economies as a major force of industry agglomeration and increased firm competitiveness was already stressed in Marshall (1920).[18] Ohlin (1933) further improved the ideas of Marshall by suggesting three central issues to better understand the location decision and competitiveness of firms. According to Ohlin, firms cluster together if they

[17] Let's again return to the Audi TT example. The production plant of Audi TT is located in Györ (Hungary), where the size of the production site is about 4 million m². At this plant, Audi employs approximately 8,600 Hungarian workers that produce about 2 million units of engines for Audi AG worldwide and 33,500 cars of models Audi TT and Audi A3. The OECD monthly average wage (in 2014) for an automotive worker in Germany is $2,336, and in Hungary the corresponding monthly wage is $500. The supply bases in Germany and in Hungary have high capabilities (van Winden et al. 2011). Rents for a 4 million m² plant in Ingolstadt (Germany) are much costlier compared to rents in Györ. The distance between Ingolstadt and Györ is about 600 kilometers, so headquarters and production site are in close proximity. Thus, in a cost perspective, it is far more advantageous for Audi AG to internationally outsource the production of Audi TT and its engine production to Györ.

[18] In this context localization economies refer to the closeness to similar firms or firms that are related in some way.

have common interests in a place with regard to the availability of i) resource endowments, ii) input supplier networks (e.g., specialized knowledge and human capital in the form of specialized labor), and iii) customers. Ohlin's major factors causing agglomeration economies included internal economies of scale, localization economies, urbanization economies (e.g., large labor pools, which induce firms to matching and information spillovers) and inter-industry linkages of input-output type. Furthermore, Malmberg et al. (2000) argue that agglomeration economies of various types should be considered in determining firms' export performance. They find, for the export performance of Swedish firms, localization economies to be less important than scale economies and urbanization economies.

Grossman and Helpman (1994) have analyzed theoretically the aspects of a firm's R&D, learning by doing and by accident, product development and international trade. In this model, the firm recognizes a cost of creating the knowledge, which it then weighs against the potential benefits of the new and improved product intended for exports. The relationship between high productivity and exports is further stressed in models by Grossman and Helpman (1995) and Melitz (2003), where the most productive domestic firms enter the market for exports. For example, the dynamic model with heterogeneous firms in Melitz (2003) analyzes the within industry effects of international trade. In this model, the exposure to trade induces only the more productive firms to enter the export market. The model emphasizes additional inter-firm reallocations towards even more productive firms if the industry's exposure to trade increases further.

Moreover, the importance of human capital for firms' export performance is noted in a vast number of empirical works. For example, Chevassus-Lozza and Galliano (2003) find that learning effects and informational spillovers in the French food industry play an important role in stimulating firms' exports to grow. Barrios et al. (2003) show that firms' own R&D is an important determinant for their export activity. Gråsjö (2008) observes that the accessibility to local human capital positively affects regional exports. Munch and Skaksen (2008) find a strong positive link between firms' export performance and human capital. Robson et al. (2012) observe that entrepreneurs with large human capital values have a greater tendency to introduce new products and process innovations, which induce firms to export more. A positive effect between human capital and the generation of new product ideas is also reported in Andersson and Johansson (2012). Johansson et al. (2014) demonstrate that firms' internal knowledge and access to employment in knowledge-intensive business services have a positive effect on both the number of product-specific export markets and average price per unit exported in local industries.

In terms of innovations and firms' export performance, Tavassoli (2014) observes that the innovation output of firms significantly improves their exporting behavior. Moreover, Lööf and Nabavi (2014) stress the importance

of the joint impact of innovations and knowledge spillovers on the productivity and growth of exporting firms. The local milieu influences firms' export performance through the combined effects of internal innovation activities and external knowledge sources. Internal innovation activities stem from firms' persistent presence in the export market, their patent applications and their regularity in the renewal of export products. The external knowledge source in the firms' local environment is proxied by the accessibility to aggregate wage sums of knowledge-intensive business services.

3.4 International Trade and Investment of Sweden

How do the patterns of international trade and investment look in Sweden? Figure 2 demonstrates that the total values of internationally traded physical goods of Sweden have grown exponentially since the end of the 1970s. Sweden has gone from a net importing country in the late 1970s towards a strong net exporter by the early 1980s.

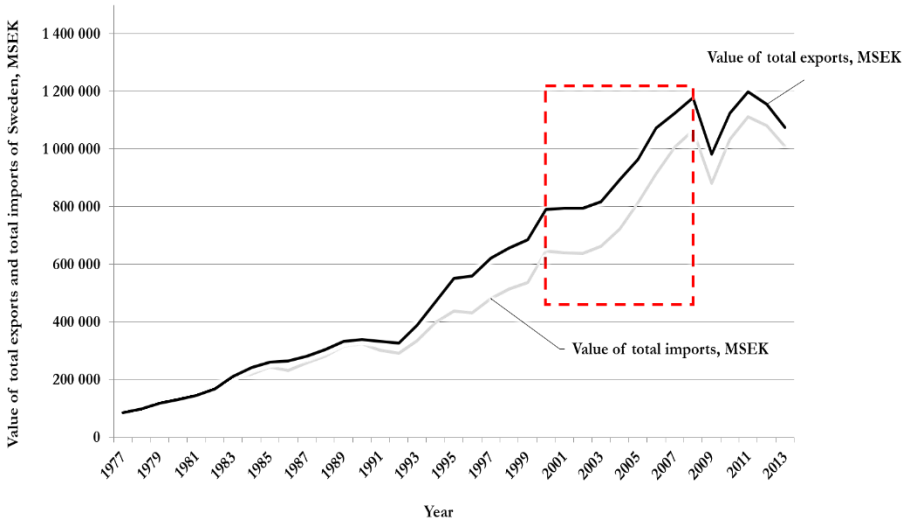

Figure 2 Value of total exports and total imports of Sweden, in SEK million, 1977-2013.

There are several underlying factors that contribute to this change. One factor, for example, is that Swedish economic policy during the 1980s favored devaluations of the Swedish currency, thus making Swedish produced goods more competitive in the world markets (Södersten 2004).

However, in later years of the time span globalization drivers such as i) improved infrastructure (in terms of highways, airports, harbors, railroads and installations of fiber optic cables); ii) advances in information and

communications technology (which promote fast communications and efficient logistics planning); iii) expansions of trade agreements (e.g., the inclusion of China in the WTO in 2001) and trade unions (such as the EU inviting more Eastern European countries as members); along with iv) multinational corporations and v) lower transportation costs (e.g., in the form of shipping containers in bulk), have contributed to an exponential expansion of Swedish economic networks during the early 1990s, with increasing cross-border flows.

Global economic networks have since the early 1960s stimulated a great amount of FDIs; however, the development of the global drivers in the 1990s has made the global economic FDIs to grow at an even more rapid pace (Warda 2013). In this way, these economic networks have freed up both capital and labor inputs to be more commonly available internationally: the former by establishing production plants with advanced machinery in foreign locations, and the latter by exploiting low cost foreign markets for their locally available labor.

Table 3 presents data on Swedish FDI for the period 2000-08.

Table 3 Swedish foreign direct investment, in SEK billion, 2000-08.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	Absolute value Δ 2000-08
Total (BSEK)	1,146	1,279	1,261	1,298	1,374	1,610	1,760	2,080	2,462	+ 215%
Europe (%)	72	70	79	77	78	76.5	80	76.5	78	+ 232%
Americas (%)	21.5	24	19	19	18	18	15	18.5	16	+ 165%
Asia (%)	1.5	1.5	1	2	2	3	3	3	4	+ 650%
Others (%)	5	4.5	1	2	2	2.5	2	2	2	– 63%
Manufacturing (%)	54	53	48	48	47	47	47	48	49	+ 197%
Services (%)	32	26	31	30	35	44	44	38	41	+ 275%

Note: The share of services includes 'trade in goods', 'banking and other financial services', 'insurance', 'hotels and restaurants', 'transport, storage and communications', and 'other services'.

Source: SCB (2009)

Europe is the most attractive region for Swedish foreign direct investment. More than 70% of the total Swedish FDI ends up in a European country. Moreover, Swedish foreign direct investment in the Americas has fallen from 21.5% of the total in 2000 to 16% of the total in 2008. A likely cause for this fall is that FDIs to both Asia and Europe are increasing over time. In terms of absolute value changes, Swedish FDIs to Asia have experienced a remarkable

growth over the period. The increase in the absolute value of Swedish FDIs to Asia is more than six-fold. However, proximity, institutions and technological structure at the destination country still prove important for Swedish FDI. The four most common countries for Swedish FDI are the USA, Finland, the Netherlands and the UK. About half of the share of the total Swedish FDI is induced by the manufacturing sector. Hence, Swedish manufacturing firms are no strangers to foreign investment. Finally, services' share of the total Swedish FDI has experienced a fast growth during the period and has increased by nearly 10%. In terms of absolute value, the increase in services is almost threefold.

No matter where the economic networks are located, locally or internationally, final and intermediate goods from these locations can be shipped directly or after re-imports be shipped to the end users globally. Thus, I apply my research to a time period of rapid increasing international trade, both export-wise and import-wise. As such, Papers 1, 2 and 3 in this thesis analyze trade-related research questions for Swedish manufacturing firms in the period 2000-08 (shown by the black-dashed rectangle in Figure 2). Papers 1 and 2 examine how imported inputs affect firms' labor demand, whereas Paper 3 analyzes how knowledge sources, both internal and external, influence the development of export products.

Before going into details on the international trade of Swedish manufacturing I will outline the general composition of international trade of Sweden.

Figures 3 and 4 present Swedish exports and imports by type of internationally traded goods for the period 2000-08. Intermediate goods trade is increasing in every year of the period examined and corresponds to the majority of Swedish exports and imports. In addition, the share of intermediate goods in total is a bit higher for Swedish imports compared to exports. In terms of total Swedish exports, capital goods and consumer goods have over the period converged into rather equal shares of about one-fourth of the total. In terms of total Swedish imports, consumer goods and especially capital goods, have lost ground to the rapid increase in intermediate goods imports. Even though the absolute values of capital and consumer goods are increasing over time, intermediate goods imports have grown strongly and have reached approximately 60% of the total in 2008.[19]

[19] Intermediate goods exclude fuels and lubricants such as motor spirits because these can be classified both as intermediate goods and consumer goods. Thus, fuels and lubricants are in this case assigned to the consumer goods category. Moreover, capital goods exclude motor vehicles, which are final goods. These are also assigned to the consumer goods category.

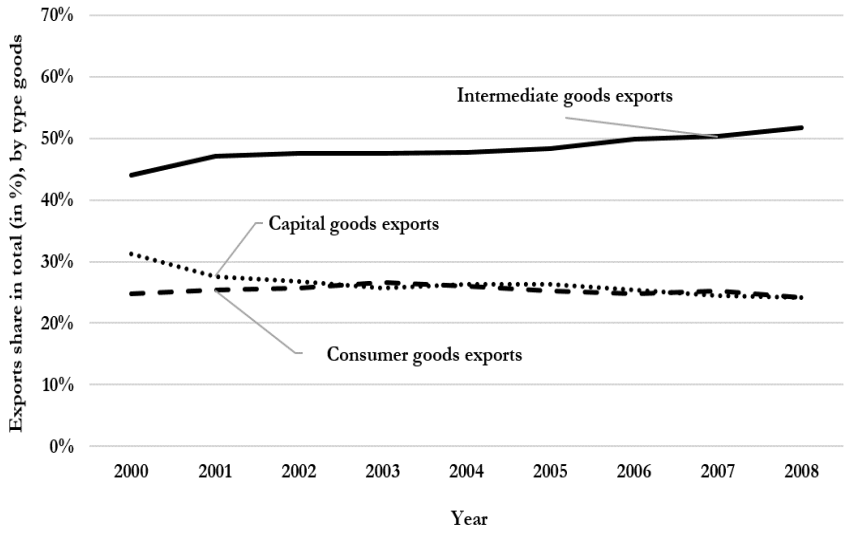

Figure 3 Exports share in total (in %), by type of goods, Sweden 2000-08.

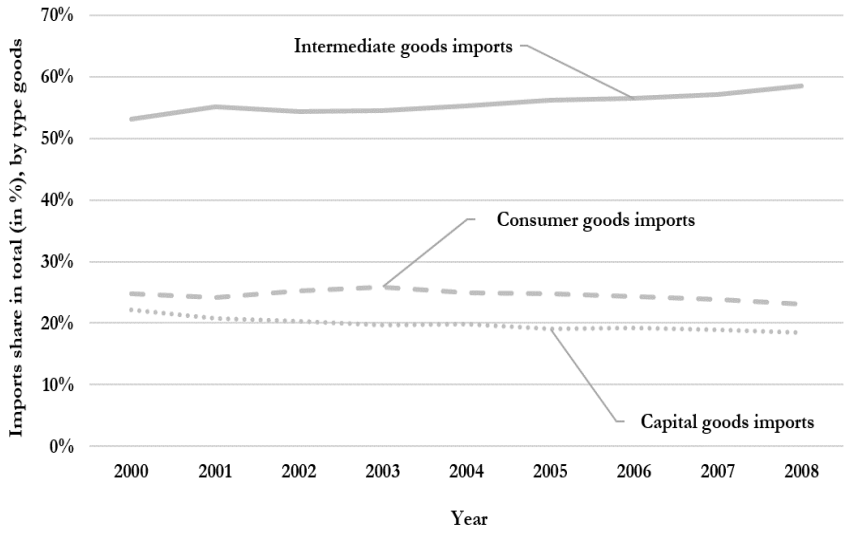

Figure 4 Imports share in total (in %), by type of goods, Sweden 2000-08.

Another interesting point refers to the destinations of Swedish exports and the origins of Swedish imports. Figure 5 presents four continents' share in total Swedish exports for the period 2000-08.[20] The figure also includes the composition of the exports in terms of consumer goods, capital goods and intermediate goods by averaging for the period. The majority of Swedish exports over the period analyzed have Europe as a destination. More than half of the exported products to Europe consists of intermediate goods, whereas consumer goods and capital goods correspond to about one-fourth of the total. Up until 2006, the Americas' share of total Swedish exports has been higher than that of Asia. In 2007, however, the Asia share of total Swedish exports has surpassed that of the Americas. The content of the exports intended for the Americas looks somewhat similar to the exports shipped to Europe. In the case where Asia is the destination, much of the exports are in the form of capital goods and intermediate goods.

Europe average 00-08:	**Americas average 00-08:**	**Asia average 00-08:**	**Other average 00-08:**
Consumer goods 26%	Consumer goods 26%	Consumer goods 20%	Consumer goods 21%
Capital goods 23%	Capital goods 28%	Capital goods 40%	Capital goods 40%
Intermediate goods 51%	Intermediate goods 46%	Intermediate goods 40%	Intermediate goods 39%

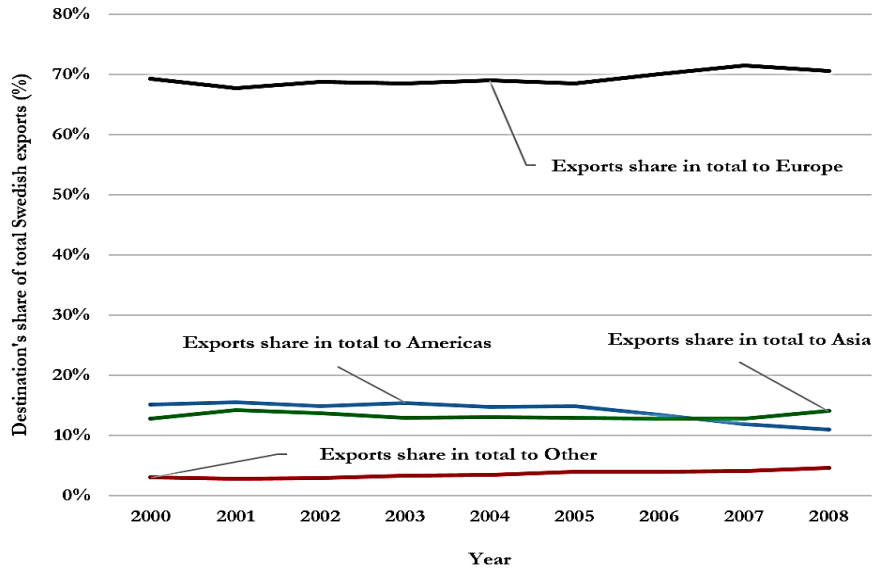

Figure 5 Destination's share of total Swedish exports 2000-08 (in %).

[20] The 'Americas' consists of North America, Central America and South America. 'Other' includes Africa and the Pacific and unknown countries that Sweden has traded with.

Turning to the origins of Swedish imports in Figure 6, again Europe is the most attractive origin of imports. In 2008, about 80% of the Swedish imports had a European origin. Intermediate goods make out the majority of the imports from Europe. The share of Swedish imports from Asia is larger than the corresponding share for the Americas, with intermediate goods strongly dominating the content of the imports from both these origins. Finally, imports from Europe and the Americas are increasing in absolute values, yet they are decreasing in the share of total Swedish imports due to the strong position of Asia. Post-2001, Asia's share of total Swedish imports increases in every year of the period analyzed.[21]

Europe average 00-08:	**Americas average 00-08:**	**Asia average 00-08:**	**Other average 00-08:**
Consumer goods 26%	Consumer goods 17%	Consumer goods 19%	Consumer goods 20%
Capital goods 19%	Capital goods 17%	Capital goods 24%	Capital goods 13%
Intermediate goods 55%	Intermediate goods 66%	Intermediate goods 57%	Intermediate goods 67%

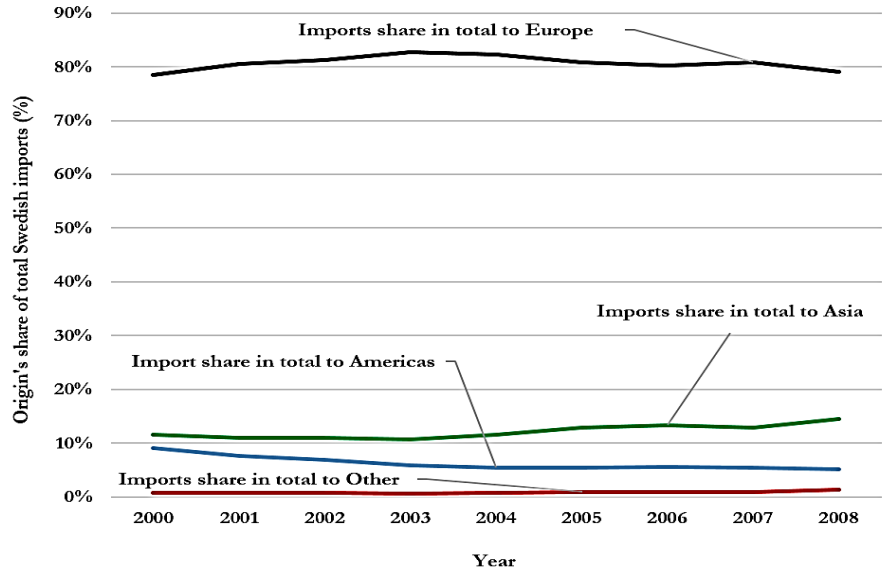

Figure 6 Origin's share of total Swedish imports 2000-08 (in %).

More than 50% of the Swedish exports and approximately 60% of the Swedish imports consist of intermediate goods. Adding on the traded share of capital goods implies that approximately 80% of the total trade in Sweden is in the form of production inputs. The remainder of this subsection will give a composition of the international trade in Swedish manufacturing. I do this by mapping exports and imports of the three classes of goods by their share of total trade in Swedish manufacturing along with their destinations and origins.

[21] Note that China enters the WTO in 2001.

3.4.1 International Trade in Swedish Manufacturing

Manufacturing's shares of exports and imports in total Swedish trade are increasing over the period 2000-08. On average, the exports in Swedish manufacturing correspond to approximately 80% of the total exports of Sweden, whereas manufacturing imports make up approximately 40% of the total Swedish imports.

Figure 7 displays the composition of the exports in Swedish manufacturing by the type of traded goods. Intermediate goods constitute the largest portion of the exports in Swedish manufacturing, and the share is steadily increasing over time. Moreover, in the beginning of the period, capital goods seem to have an advantage over consumer goods. However, in more recent years the exports of consumer goods surpass capital goods exports. As the absolute value of intermediate goods exports has increased substantially over the whole period, exports of consumer goods and capital goods have experienced smaller absolute value increases. In this way, both the consumer goods and the capital goods obtain a smaller chunk of the total exports in Swedish manufacturing. Knowledge processes in Swedish manufacturing are important inputs in the global production of final goods, which are reflected in the majority of exports in Swedish manufacturing constituting intermediate goods.

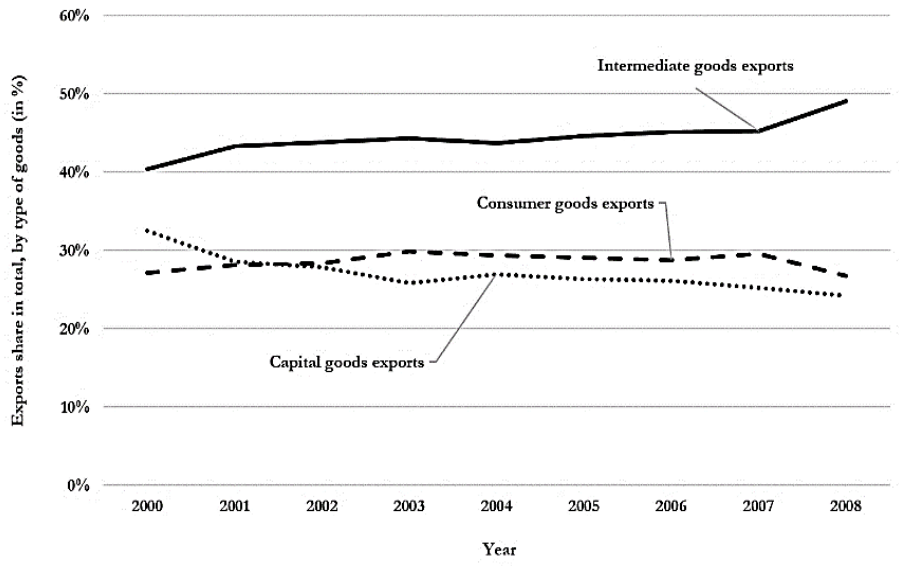

Figure 7 Exports share in total (in %), by type of goods, Swedish manufacturing (SNI 15-36) 2000-08.

Figure 8 shows that imports in Swedish manufacturing follow a similar trend as do exports in Swedish manufacturing. However, note that the intermediate goods imports share in total imports in Swedish manufacturing is approximately 10% higher compared to the exports.

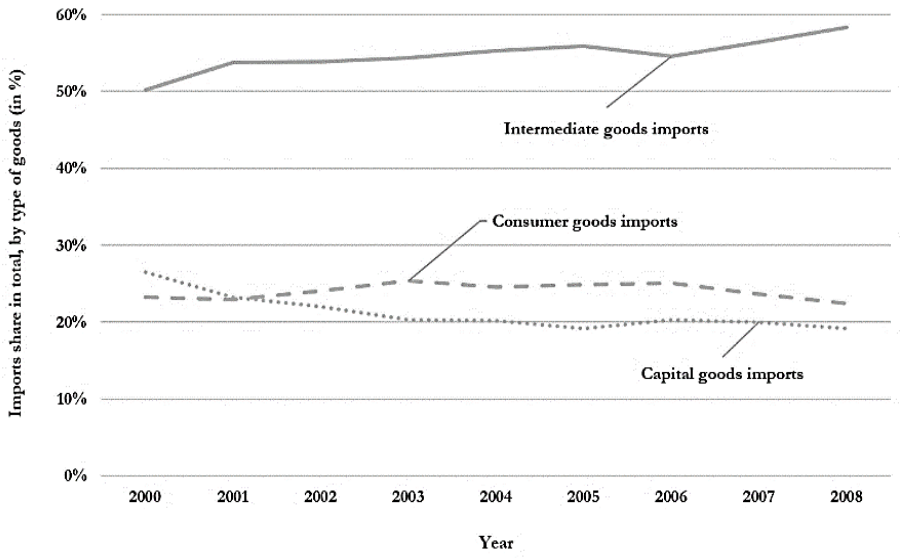

Figure 8 Imports share in total (in %), by type of goods, Swedish manufacturing (SNI 15-36) 2000-08.

Table 4 breaks down the exports and imports into some selected industries in Swedish manufacturing. The high-technology industry 'medical and optical instruments' has, on average, exports and imports with the highest mean price, lowest mean weight, and longest mean distance. The most important continents per destination are Europe and Asia, whereas Europe, Asia and the Americas are important origins. For all industries, Norway is the number one export destination. On the other hand, imports originate mostly from Germany and the USA. The highest share of intermediate goods in both exports and imports is observed in 'medical and optical instruments'. 'Machinery and equipment' is dominated by exports and imports containing capital goods. Consumer goods are typically contained in the exports and imports of the industries 'textiles' and 'automotive'. Finally, the industry 'machinery and equipment' is by all means the industry with the most traded goods.

Table 4 International trade characteristics of some selected in industries in Swedish manufacturing, average of period 2000-08.

Trade characteristic	Exports					Imports				
	Textiles	Machinery and equipment	Electrical machinery	Medical and optical instruments	Auto-motive	Textiles	Machinery and equipment	Electrical machinery	Medical and optical instruments	Auto-motive
Price in SEK per unit, 2000-08										
Mean price	611	1,181	2,421	5,193	638	515	1,510	2,130	7,248	2,942
Mean price consumption goods	320	143	322	426	87	193	228	481	1,275	693
Mean price capital goods	37	473	859	1,383	189	71	523	634	2,565	810
Mean price intermediate goods	254	564	1,240	3,384	362	251	759	1,014	3,408	1,438
Weight in kg, 2000-08										
Mean weight	10,956	13,115	14,369	2,759	33,480	13,287	17,547	15,047	2,661	94,584
Mean weight consumption goods	9,385	1,447	7,320	42	27,884	4,982	1,719	2,668	77	41,278
Mean weight capital goods	325	8,780	2,642	331	3,297	346	7,695	3,413	183	8,909
Mean weight intermediate goods	1,246	2,889	4,407	2,387	2,299	7,958	8,132	8,966	2,400	44,398
Distance in km, 2000-08										
Mean distance	2,430	3,780	3,595	4,242	3,995	2,286	3,081	3,023	4,242	2,154
Mean distance consumer goods	1,031	457	508	345	800	813	426	522	569	562
Mean distance capital goods	172	1,625	1,085	877	1,091	189	1,106	864	1,095	555
Mean distance intermediate goods	1,226	1,687	1,998	3,010	2,101	1,284	1,547	1,636	2,569	1,036
Destination/origin, 2000-08										
Top 1 continent	Europe	Europe	Europe	Europe	Europe	Europe	Europe	Europe	Europe	Europe
Top 2 continent	Asia	Asia	Asia	Asia	Asia	Asia	Americas	Asia	Americas	Americas
Top 3 continent	Americas	Americas	Americas	Americas	Americas	Americas	Asia	Americas	Asia	Asia
Top 1 country	Norway	Norway	Norway	Norway	Norway	Germany	USA	Germany	USA	Germany
Top 2 country	Finland	USA	USA	USA	Belgium	Norway	Germany	USA	Germany	Belgium
Top 3 country	Denmark	Germany	Finland	Germany	Finland	Denmark	Norway	Norway	Norway	UK
Goods' share in total, 2000-08										
Consumer goods (%)	80	15	26	3	85	51	13	23	10	49
Capital goods (%)	3	60	30	20	11	5	44	24	20	16
Intermediate goods (%)	17	25	44	77	4	44	43	53	70	35
Total traded goods , 2000-08										
Total goods	6,567	70,588	13,624	18,909	42,894	5,126	28,550	9,719	10,706	12,719
Consumer goods	2,453	8,549	2,078	1,640	8,800	1,878	3,587	1,631	1,410	2,995
Capital goods	541	30,266	4,086	4,135	11,760	406	10,582	2,607	2,762	3,363
Intermediate goods	3,573	31,774	7,459	13,133	22,334	2,842	14,381	5,481	6,534	6,361

4 Data Utilized in the Thesis

This section presents some of the properties of the data utilized in Papers 1 through 4 in this thesis. Subsection 4.1 deals with the details on the firm level data employed in Papers 1, 2 and 3. Subsection 4.2 outlines the procedure followed in the meta-analysis to obtain the data utilized in the meta-regressions in Paper 4. The thesis papers in the sequel are:

Paper 1: Labor Demand - The Role of Imports in Production,

Paper 2: Offshoring, Occupations and Job Tasks - Evidence from Swedish Manufacturing,

Paper 3: Knowledge Absorption in the Development of Export Products,

Paper 4: Spatial Knowledge Spillovers within and between European Regions - A Meta-Analysis.

4.1 Data in Papers 1, 2 and 3

The data employed in Papers 1, 2, and 3 consist of publicly audited micro-level data collected by Statistics Sweden. The data include detailed information on employees, firms and establishments.

Employment data are reported in terms of educational attainment (e.g., the number of schooling years, or the type of degree such as high school diploma, tertiary degree in specialized programs shorter than three years, bachelor of science, master of science, or a doctoral degree), gender, age, income, and occupation. Firm data include information on production inputs such as the number of employees, imports, and physical capital (e.g., holdings of land, buildings and machines). The firm data also report information on value added and exports, and other firm characteristics such as age of the firm and ownership. In addition, price per unit in SEK, quantity in kilograms, product code, destination and origin are available for the export and import data. Furthermore, the product codes of the exports and imports are reported at the eight-digit level and with the Combined Nomenclature (CN). CN can be linked to the Standard International Trade Classification (SITC), or to the Harmonized System (HS), where the latter gives a direct link to the Broad Economic Categories (BEC). A further note on the export and import data is that the product codes have been re-coded by using concordances tables to follow the same combined nomenclature over the period analyzed. That is, the export and the import data follow the CN of 2008. Establishment data refers to the number of establishments per firm.

The focus in this thesis is on manufacturing firms in Sweden during the period 2000–08. Manufacturing firms in this context refer to all firms in

Sweden that belong to the Swedish standard industrial classification (SNI) 15-36.[22] The population includes import data on approximately 60,000 observations for 17,243 unique firms over the nine-year period and approximately 66,000 observations for 15,449 unique export firms. The data are tied by identity codes in terms of the above three units (i.e., employee, firm, and establishment). This convenient structure of the data allows for tying the employee data on educational attainment to an establishment and a firm, and the number of establishments to a specific firm. Another strength of the dataset is that it follows the same reporting in the SNI coding (i.e., SNI 15-36) throughout the period 2000-08. Thus, the period analyzed allows one to follow a specific firm over the nine years, and reduces the possibility to lose track of a firm, that due to changes in the industry coding disappears from the population. Aside from these strengths, there are also some additional notes worth mentioning regarding the trade data in Papers 1, 2 and 3.

Paper 1 deals with imported inputs in terms of capital goods and intermediate goods. The imports in this paper are distinguished by quality, which is approximated for by using the import price per unit of input. The quality of an imported capital good or an imported intermediate good can take on two distinct forms, either high or low. The import price per unit of good contained in product group is obtained by dividing its import value with its weight. I then calculate the average import price per unit in each product group.[23] A high quality import is then defined as a good where the ratio of its import price per unit divided by the average import price per unit in its product group is larger than unity. Moreover, a low quality import has a ratio less or equal to unity. A possible limitation in constructing the import variable based on inputs only is that consumer goods are disregarded in the import data. However, since the focus in this paper is on how the qualities of inputs used in the production interact with the manufacturing firms' labor demand, consumer goods imports (which are final goods) are redundant in the analysis.

The offshoring variable in Paper 2 is approximated from a standard production function. The sales value of a firm can be divided into value added (i.e., labor cost plus gross profit) and costs of inputs (of which some are imported). The sales value less value added, thus gives an approximation of the firm's total input costs. The firm's domestic consumption is then given by its total input costs less what is exported and plus what is imported by the firm in terms of intermediate goods. Dividing the firm's imports of intermediate goods by its domestic consumption gives a broad measurement of the firm's

[22] The industry classification is based on SNI1992 and SNI2002 published by Statistics Sweden.

[23] The product groups in this process have been narrowed down to the four-digit level of the CN for 2008.

offshoring activities.[24] The offshoring variable in this paper also considers the intermediate good's price per unit and its quantity to determine a proxy for its technological content. This approach is somewhat different from the previous studies in the field (cf. Feenstra and Jensen (2012) and Nilsson Hakkala et al. (2014)), yet the strong microeconomic foundation remains.

In Paper 3, we analyze how the knowledge absorption across municipalities and local labor markets influences the development of export products in Swedish manufacturing firms. For this purpose, we use data on exports, which are reported as firm aggregates. In order to create our proxy variable for new export products we treat all the export products as new in the first year of the period. Then, if a firm introduces new product codes in any of the subsequent years to the first, these are counted as new export products.[25] Since a firm can locate in several municipalities, it infers a limitation that needs to be carefully considered. For example, if a firm has establishments in several municipalities, this causes a problem in assigning the export data to a certain establishment. To handle this problem, we follow two procedures in i) assigning the export aggregate, and ii) suggesting a possible robustness check for our main model. Thus, we do the following to approach the problem:

i) In case of a multi-location firm, we assign the export aggregate to the location with most employees and run our model for the full panel.

ii) As a follow-up robustness check, we reduce the size of our panel to include only single establishments and then estimate our model in order to compare the result with those obtained using the full panel in i).

4.2 Data in Paper 4

In Paper 4, the data for the meta-analysis has been collected via an extensive search for publications that correspond to a set of lowest common denominators. The period for the publications analyzed ranges from 2000–13. Keywords that have been used to find publications of interest consist of i) 'knowledge production function' and 'Europe' and 'knowledge spillovers' and 'Europe'. Through backward induction, we have used the reference lists of matching publications to find related publications in order to construct a meta-sample. Additional requirements made for a specific publication to be included in the meta-sample are ii) quantitative methods are applied, iii) the publication must contain a specific knowledge coefficient that measures local and/or spillover knowledge effects from one region to another, and iv) the publication analyzes a minimum of five European countries.

[24] Current inputs (such as machinery equipment and other capital goods) and consumer goods are filtered out by converting the eight-digit level of the CN into HS, and the HS into BEC.

[25] All export products have been recoded to follow the CN for 2008.

From 19 publications we have managed to extract local knowledge effects (β_1) in all publications.[26] The local knowledge variable (x_i) is frequently reported in terms of R&D expenditure. On the other hand, the knowledge spillover effect (β_2) has been far more difficult to interpret due to various methodologies adopted in the empirical regression analyses of these publications. In this way, we have been able to isolate 160 observations for β_1, and only 96 observations from 11 publications for β_2. Most commonly, the knowledge spillover variable (Wx_j) takes the form of R&D weighed contiguity matrices. Equation (7) shows a typical knowledge production function that has been employed in the publications that constitute our meta-sample

$$Y_i = \alpha_0 + \beta_1 x_i + \beta_2 W x_j + \sum_{k=1}^{n} \gamma_k \, v_{ki} \, , \qquad (7)$$

where γ_k is a coefficient and v_{ki} is a vector that measures other covariates in region i. The β_1 and the β_2 that we have extracted from the publications will take the form of dependent variables in our meta regressions in Paper 4. In Equation (7), the dependent variable (Y_i) is mostly reported as logged yearly patent applications in region i, or as logged yearly patents in region i. Our β_1 and β_2 will thus be interpreted as effects in terms of local patents production.

Other covariates of interest that we have encountered in v_{ki}, and control for in terms of dummy variables are time period, time lag between input and output, coverage of the economy (manufacturing, services or total), type of data (e.g., panel data or cross-section data), initial patent stock, number of observations, focus area in Europe (e.g., north, east, west and south, or a combination of these focus areas), statistical significance (in terms of t-values and p-values), estimation method (e.g., ordinary least squares, generalized least squares or maximum likelihood), type of spatial model, main explanatory variables and controls, geographic unit (NUTS), and other variables of interest that characterize each publication. After having constructed the meta-sample, meta-regression analysis is applied to evaluate the spatial spread of knowledge, in terms of local patents production, within and between European regions.

A possible limitation of this meta-sample could be that the sample size is rather small. However, we have reviewed more than 100 publications in total and selected about 50 publications for further analysis. The majority of this selection has used irrelevant methods of interpreting the knowledge variable, or a quantitative approach not suitable for our purpose, thus narrowing down our meta-sample to 19 publications.

[26] Since most publications run several regression models the number of beta coefficients per publication can exceed 1.

5 A Summary of Thesis Papers 1-4

In this final section of the introduction I present four research questions that address how knowledge can travel in space (see Table 2 for the details on the knowledge inputs and the knowledge outputs). Each research question forms an individual paper and can be read separately. Papers 1 and 2 are self-authored, whereas Papers 3 and 4 are co-authored. Paper 3 is co-authored with Börje Johansson and Paper 4 is co-authored with Urban Gråsjö and Charlie Karlsson. Each paper is outlined here with its motivation, purpose and contribution, main findings and suggestions for future research.

5.1 Paper 1: Labor Demand – The Role of Imports in Production

Motivation

Paper 1 is motivated from an interest in how drivers of globalization (such as i) to v) outlined in Subsection 3.4 of this introduction) have initiated an increase in world merchandise trade. These global drivers are keys for making firms into global production plants. Furthermore, the drivers of globalization have motivated immobile labor supplies to become highly mobile across international borders, across nodes in intra-firm networks, and across nodes in inter-firm networks.

My focus in this paper is on Sweden, which is a country that strongly characterizes trade in inputs and where firms, especially in the manufacturing sector, have pushed enormous sums of foreign investment to new markets in Europe, the USA and Asia. Against this background I state my first research question, which is motivated by a period of rapid growth in imported production inputs:

Can import quality influence firms' labor demand?

I argue that firm-level imported inputs of different qualities may contain hidden sources of knowledge that require employees to have a certain level of education once the inputs are adapted into the production of final goods.

Purpose and contribution

I analyze how high- and low-quality imports (in terms of capital and intermediate goods) influence the labor demand in importing firms of different sizes in Swedish manufacturing.

Paper 1 contributes to the literature by increasing our knowledge on how imported inputs interact with the labor demand in micro, small, medium, and large firms. In addition, the paper suggests the type of trade policy to follow to increase job sustainability in firms.

Main findings

The demand for labor with a high level of education tends to grow with high-quality imports in all firm size categories. High-quality imports in this case work as production complementarities as they are likely to contain advanced semi-processed inputs that need to be processed by labor with some form of tertiary education, for example by trained engineers. Furthermore, the empirical results are clear for high-quality imports impact on firms' demand for labor with a low level of education. Here, the results for all firm sizes show that the correlation is negative, which indicates substitution in the home production. Thus, firms with high-quality imports substitute labor with a high level of education for labor with a low level of education.

The relationship between low-quality imports and firms' demand for labor with a high level of education is positive in micro, small and medium firms; however, this relationship is negative in large firms. A possible reason for the positive relationship can be that labor with a high level of education in micro, small and medium firms is more flexible in the home production compared to large firms. For example, the limited number of labor in micro, small and medium firms might work in favor of involving an engineer, a manager or a CEO in the production of final goods. Large-sized firms, on the other hand, might characterize routinization in processing inputs, which gives a more distinct division of labor in the home production. Moreover, low-quality imports impact on labor with a low level of education is neutral in micro, small and medium firms; however, in large firms, low-quality imports bring production complementarities for labor with a low level of education.

In the majority of cases, imported inputs tend to be more job-creating than job-diverting, at least for trained engineers. However, trade policies should be designed to help promote trade flows that induce production complementarity, e.g., to be aimed at carefully selected semi-processed goods. Such trade policies can increase the labor demand in all types of firms, from micro-sized firms to large-sized firms.

Suggestions for future research

A suggestion for future research regards the findings observed for large firms. Offshoring patterns, as indicated by the descriptive data and previous research, seem to come with consequences for labor with a high level of education in large firms. In large firms, the majority of imports consists of low-quality inputs, and large firms' share of the total R&D in Swedish manufacturing is about 70%. Thus, one may ask what the consequences are for R&D processes in Swedish manufacturing if, for example, large firms continue to substitute low-quality imports for trained engineers. To retain the labor with a high level of education in large firms in Sweden is crucially important for future R&D growth, innovations and for improving the Swedish competitiveness in the global economy. Thus, a thorough analysis on offshoring's implications on large firms' R&D is called for.

5.2 Paper 2: Offshoring, Occupations and Job Tasks – Evidence from Swedish Manufacturing

Motivation

Similar to Paper 1, my motivation for the research presented in Paper 2 is underpinned by globalization drivers that have generated rapid increases in international trade and foreign investment by Swedish firms. Along with this development, I find another highly interesting phenomenon taking place in Swedish manufacturing. The occupation categories in offshoring firms in Swedish manufacturing depict a clear change in their structures. During the first decade of the new millennium, motoric (goods-handling tasks) occupations in total are decreasing, whereas cognitive (knowledge-handling tasks) and management (information-handling tasks) occupations in total are increasing. With this background I pose a second research question:

> *Does it matter to employees' occupations and their associated job tasks what technological content the intermediate goods imports characterize when firms engage in offshoring?*

I argue that a firm's decision to offshore affects certain employees' occupations and job tasks in the firm differently depending on the technological content of the imported intermediate goods. I fine tune the import variable used in Paper 1 to only include semi-processed goods as a share of firms' domestic input consumption. Moreover, I bring in a technological feature to the semi-processed goods by considering both their price per unit and their total weight. This way to construct the offshoring variable is somewhat different from the offshoring measures that have been encountered in previous studies.

I further claim that a misspecified offshoring variables might be a reason for the conflicting results presented in recent empirical research. For example, Foster-McGregor et al. (2013) use data for various countries (including all the EU27 countries) and observe that offshoring has impacted negatively on all skill levels. Görg et al. (2013) use German data and find that offshoring favors non-routine labor, whereas routine labor suffers from negative wage effects. Antonietti and Antoniolo (2011) use Italian data and find no empirical evidence on offshoring's impact on the relative skills structure in manufacturing firms. However, by separating the skills ratio, the skills bias is found to be driven by a fall in blue-collar workers, rather than an increase in white-collar workers. Nilsson Hakkala et al. (2014) use Swedish data on multinational firms and observe that offshoring's effect on the wage cost share of non-routine job tasks is neutral.

Purpose and contribution

I analyze how offshoring of intermediate goods affects different occupational groups in Swedish manufacturing firms using data for the period 2001-08.

The research in this paper comes with several contributions. First, the empirical results give a quantitative evaluation of what types of labor occupation and their associated job tasks are affected in offshoring firms. This evaluation is thus important for politicians, not only to form socially optimal policies for the unemployed in Swedish manufacturing firms, but also in forming future education and training policies. Second, my results contradict the insignificant offshoring firm-level estimates observed in previous research. A potential reason for the lack of evidence in previous research is that the offshoring variable is misspecified. Third, the methodology used to proxy firm-level offshoring in this paper is somewhat different from that of previous studies, and in this way, it contributes to the existing literature.

Main findings

Two main hypotheses are tested in the empirical analysis of this paper. The first hypothesis addresses imports of intermediate goods that contain technology-rich inputs in the final production. This type of intermediates require employees with job tasks involving knowledge handling in the manufacturing firm. For example, a microscope needs to be assembled by someone that has knowledge on the functionality of optic components, and this someone is likely to have an engineering background. Thus, employees with cognitive occupations benefit from complementarity effects in the production of final goods when offshoring of a firm is rich on technology.

Imports of intermediate goods that have a low-technological content consist of more routine-based inputs in the final production. Therefore, the second hypothesis suggests that more employees associated with goods-handling tasks are demanded by the manufacturing firm. For example, processing and packaging meat for the food production industry do not require an employee to have an engineering degree. Thus, employees with motoric occupations benefit from complementarity effects in the production of final goods when offshoring of a firm is low on technology.

The empirical results are consistent with the stated hypotheses and show that increased high-technology intermediate goods offshoring increases the cost share of employees with cognitive occupations, and decreases the cost share of employees with motoric occupations. Increased low-technology intermediate goods offshoring positively influences the cost share of employees with motoric occupations, whereas the cost share of employees with cognitive occupations is affected negatively.

The main message of this paper is that what we put into the domestic production of final goods requires the 'right' employees to figure things out. If an input is of complex standards, then the firm demands employees who can address the complex standards. If the input is naturally simple to process in the domestic production of final goods, then the firm demands employees who mesh with such processes. What we need is to better integrate the technological contribution of the input itself into our approximation of offshoring because,

in the end, the 'right' employee needs to put the inputs together to produce the firm's output.

Suggestions for future research

An extension of the work presented in this paper may be to conduct an empirical study on the services sector and the retail sector, where offshoring is a common strategy. In services, offshoring high-technology services involves activities related to R&D and information and communications technology; in retail, offshoring typically involves production of sketched product designs. Increased offshoring in services and retail implies less sourcing of Swedish firms. Thus, an evaluation on offshoring's effect on employees' occupations in these two sectors is of high importance.

5.3 Paper 3: Knowledge Absorption in the Development of Export Products

Motivation

This paper finds its motivation in the work of Cohen and Levinthal (1989), who argue that a firm's internal knowledge enhances both its efficiency of basic operations and its renewal activities. Furthermore, Cohen and Levinthal (1990) extend their arguments to claim that the internal knowledge of the firm improves its capacity to absorb and exploit the external knowledge that can help the firm to create and adopt new innovations.

Developing new export products comprises activities such as monitoring novelties in the market, imitating and adopting new technical solutions, R&D efforts and innovation. All these activities are assumed to benefit from internal knowledge that the firm has accumulated by recruiting employees who embody knowledge and know-how and by accumulation of experiences from R&D efforts. This outline motivates us to raise a third research question related to the firm's internal knowledge, its external knowledge potential, and the conjunction of the two:

> *Does the conjunction of a firm's internal knowledge and its external knowledge potential (call it absorptive capacity) imply that the firm improves its development of export products?*

The relevant knowledge comprises know-how both about product development activities and procedures for penetrating new customer markets. The internal knowledge intensity of the firm is reflected in its employees with a specialized training degree from a university and/or college where the program duration is less than three years, a bachelor's degree, a master's degree, or a doctoral degree. Moreover, we measure the external knowledge potential by the access to the employment in Knowledge-Intensive Business Services (KIBS).

Purpose and contribution

We analyze how firms' knowledge absorption capacity affects the development, adoption and introduction of new export products among Swedish manufacturing firms.

In this paper we introduce a model that quantitatively examines the role of a firm's absorptive capacity on its new export products. As such, our main contribution is that we can empirically observe how a firm's knowledge intensity in conjunction with its external knowledge potential affects the frequency of its introduction of new export products.

Main findings

Our analysis demonstrates that the relative size of the internal knowledge affects the character of new export products by i) making export sales larger, ii) making the number of new export products larger, and iii) augmenting the export price of the new export products. In addition, the greater price level is combined with a larger number of products sold in smaller quantities.

The conjunction variable predicts a similar pattern of consequences for the new export products – as does the internal knowledge. Thus, an augmented price, a larger set of new varieties, and smaller quantities combine into an increased value of total sales of new export products.

Moreover, explanatory variables that reflect scale, such as size of labor and physical capital, impact the price downwards and the quantity per variety sold upwards. This means that the effect of the internal knowledge intensity and the knowledge conjunction variable is more pronounced for smaller firms.

Amongst exporting firms, the probability of introducing new export products increases with the size of internal and conjunction knowledge, and with the size of the firm. The probability is significantly higher for firms belonging to a multinational company group, which may reflect access to global knowledge sources. Thus, we suggest that a firm which decides to introduce a new export product either already has the necessary internal and conjunction knowledge or it adds new knowledge as an integral part of the introduction decision.

Finally, applying our regression model for total export sales of exporters that do not introduce new export products reveals that this group of exporters is governed by a different logic.

Suggestions for future research

Two observations on the firm's external knowledge potential suggest additional research. The first observation is the strong correlation between KIBS and Knowledge-Intensive Manufacturing Industries (KIMI). Second, the firm's external knowledge can be further enriched with explicit details on knowledge suppliers by using the Community Innovation Survey (CIS) database. Thus, there are alternative measures to adopt in future research in order to reflect on the firm's external knowledge potential in relation to its development of export products.

5.4 Paper 4: Spatial Knowledge Spillovers within and between European Regions – A Meta-Analysis

Motivation

The motivation for this paper is rooted in the substantial increased interest in the topic of 'knowledge spillovers'. An increased interest is found, not least among policy makers in Europe, but also among researchers. Developments in endogenous growth theory during the three last decades has undoubtedly stimulated the interest among researchers. Some examples include the Knowledge Production Function (KPF) presented in Griliches (1979), Jaffe's (1989) extension of the KPF to include a geographical dimension, and Anselin's (2003) extension of the KPF into a spatial dependence framework. Given all these developments of the KPF, we are encouraged to ask a fourth research question that is worthy of some reflection:

Do spatial knowledge spillovers exist, and if so, to what extent do they spill over?

A unique contribution to the previous research on knowledge spillovers would be to gather empirically documented data by means of meta-analysis. By determining the extent and the spatial reach of such spillovers, we apply meta-regression analysis to evaluate the determinants of observed heterogeneity across and between publications in the meta-sample.

Purpose and contribution

The purpose of this paper is to quantitatively review the empirical literature on spatial knowledge spillovers in Europe through meta-analysis to determine the extent to which such spillovers have been empirically documented, as well as their spatial reach.

Aside from being the first study of its kind, the empirical information on knowledge spillovers in this paper is particularly important for the design of policies at the EU, national and regional level, aimed at increasing knowledge production and economic growth. In addition, this study also serves as a source of inspiration for future research that uses meta-regression techniques on a meta-sample of studies that adopt the KPF.

Main findings

Three aspects of our results are noteworthy to reflect upon.

The first concerns the spatial reach of knowledge spillovers. In terms of local European regions, investment in knowledge related activities (e.g., in the form of R&D expenditures) tends to augment local patent production. The analysis also reveals that the spillovers from R&D expenditures in non-local regions have a positive effect on local patent production; yet, such knowledge spillovers tend to be small. Moreover, the spatial weighting regime for non-local R&D expenditures appears relevant. If R&D expenditures in other

regions are weighted by distance in kilometers or minutes (instead of a binary contiguity matrix), then the spillover effect on average will be larger. Thus, we find empirical evidence for both local and non-local effects on local patents production; however, the economic significance of the local effects is much stronger compared to the non-local effects.

The second aspect is that the total local R&D expenditures are more efficient for local patent production when allocated via private funding networks rather than via public funding streams. University research does not generate as much to patent growth as private firms do. This finding might be the result of private firms' R&D activities being monitored more efficiently, and because knowledge generated thereby is commonly earmarked in terms of patents to protect the discovery for future adaptation. It could also be that much university research spins off to the private industry, which in this way contributes to regional growth through more innovative private firms.

The third aspect concerns R&D activities that occur in local regions in western and southern Europe. R&D expenditures in local regions in western and southern Europe generate positive benefits in terms of increasing local patent stocks, whereas the effect is the opposite when knowledge spills over from non-local regions. Thus, there is a strong tendency for local patent production to be driven by local R&D expenditures. This result indicates that the policies of the Lisbon agenda and the EU2020 need to stimulate further innovation, competitiveness and economic growth throughout Europe by considering the spatial reach of knowledge spillovers.

Suggestions for future research

The results from our meta-regressions are most interesting in some aspects. However, it is highly important to stress that further research on spatial knowledge spillovers is needed in order to give answers that are more specific on the spatial scope of how knowledge spreads within and between regions. Hence, there are no previous quantitative studies in this topic using meta-regression analysis with which we can compare our results. The limited research makes it rather difficult to propose a specific policy recommendation to motivate knowledge production and economic growth in Europe. Thus, we call for more quantitative studies that use meta-regression techniques before we can make any in-depth conclusions on policy recommendations. A suggestion is to expand the meta-sample of the present study to include future publications in this topic.

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