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Theoretical Perspectives on the International Transfer and Diffusion of Climate Technologies

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Abstract

Enhancing developing countries' access to climate technologies can provide a significant contribution to addressing climate change on a global scale. However, the issue of international technology transfer has remained underexplored in the climate policy literature and more research on the role of climate technology firms is needed. However, simply revisiting existing firm-level theories about the firm's internationalization behavior and technology transfer strategy with a view on climate technology would not be sufficient given that the objective is a widespread technology diffusion. In addition, these theories need to be closer aligned with the extant literature on knowledge spillover and technology diffusion which provides answers to the question why some developing countries are able to absorb foreign technology successfully, whereas others are not. Taking this as a starting point, the paper relates firm-level theories on internationalization and transfer channel choice to the literature on knowledge spillover and technology diffusion with the help of a simple framework. This framework is then applied to the issue at hand: the international transfer and diffusion of climate technologies. Implications are derived for climate technology firms as well as for the countries involved in the transfer process.

Keywords: International Technology Transfer; Climate Technology; Transfer Channel; Knowledge Spillover; Technology Diffusion

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1 Introduction

Enhancing developing countries' access to climate technologies can provide a significant contribution to addressing climate change on a global scale. The UN Framework Convention on Climate Change (UNFCCC) has included provisions on international technology transfer from the beginning; even though the issue has largely been neglected for the first fifteen years after its inception (Verbeken, 2012). This fact was also acknowledged by the 2007 Conference of the Parties in Bali, where an Action Plan was adopted that led to the creation of the UNFCCC's Technology Mechanism in 2010. Experiences with existing political initiatives within the UNFCCC and the WTO show that the "success of the technology transfer processes lies not in how many international obligations exist for the purpose, binding and non-binding, but rather on how [these] are structured around ground realities of technology acquisition and use processes" (Sampath and Roffe 2012, 48).

As most climate technologies are developed and sold by firms, the success of global actions to mitigate or adapt to climate change is not based solely on the willingness of governments to fund the transfer of knowledge and technology to developing countries, but also quite significantly on decisions made by the owners of the technology, which are in most of all cases companies from OECD countries, and other factors influencing technology diffusion and innovation in the South. De Coninck and Sagar (2015, p. 1) arrive at the conclusion that the issue of international transfer of climate technologies "remains relatively underexplored in the climate policy domain, in part because of its enormous complexity and context-dependence..." Likewise, Kolk (2013, p. 1) states that "…the characteristics and drivers peculiar to international companies have remained underexposed in the policy-related literature on clean technology transfer and development."

However, simply revisiting existing firm-level theories about the firm's internationalization behavior and technology transfer strategy with a view on climate technology would not be sufficient given that the objective is a widespread diffusion of climate technology. In addition, these theories would need to be closer aligned with the extant literature on knowledge spillover and technology diffusion which provides answers to the question why some developing countries are able to absorb foreign technology successfully and to build own innovation capacities, whereas others are not. The literature on knowledge spillover usually takes a specific transfer channel as a point of departure, e. g. foreign direct investment (FDI), and then empirically analyses the impact on the recipient country's productivity. This research strategy, however, largely disregards the nature of decision-making processes that take place before firms enter a foreign market. In this context, firms will take into consideration many different aspects which are specific to the firm, the technology and the recipient country. For example, Enercon, one of the global technology leaders in the field of wind power, has decided not to sell its products to the USA and China because of the risk associated with both markets. Furthermore, transfer channels differ in their ability to transfer firm-specific tacit knowledge components which are often regarded to be crucial for the full mastery of a technology. Thus, the choice of an inappropriate transfer channel can influence technology diffusion negatively because of the higher costs that have to be incurred by the technology. These arguments make clear, that the extent in which knowledge spillover and technology diffusion can be realized is highly dependent on strategic considerations of the technology supplier.

Taking this as a starting point, the following analysis will relate firm-level theories on internationalization and transfer channel choice to the literature on knowledge spillover and technology diffusion with the help of a simple framework. The study is structured as follows: Chapter 2 will give background information on the international transfer of climate technologies. Chapter 3 introduces a framework for the analysis of international technology transfer and briefly summarizes relevant strands of the economic literature. Finally, in chapter 4, firm-level and country-level implications for the international transfer of climate technologies are derived.

2 Background

2.1 Economic Peculiarities of Climate Technologies

The emergence of climate technologies can be perceived as a process of ongoing technological change. However, climate innovation or, to put it more generally, environmental innovation is subject to a double externality problem (Rennings, 2000).

First, eco-innovation, just like other types of technological innovation, produces positive knowledge externalities. This externality is caused by the public-good nature of knowledge which leads to the fact that other firms can also benefit from the knowledge created by the innovator. Thus, competition will drive the prices of the products resulting from the innovation down to a certain degree because social institutions to prevent imitation, such as patents, are always imperfect (Jaffe, Newell, & Stavins, 2005). Second, in addition to the first externality problem, eco-innovations are faced with a second externality problem in their diffusion phase, because adopting eco-innovations generates positive externalities for the environment.

As a consequence of these externalities, the innovator will only be able to capture a fraction of the rewards from his innovation efforts. Thus, incentives for eco-innovation are reduced which results in the fact that private investment in innovation will be smaller than socially desired. In order to overcome these market failures, specific environmental and technology policies are considered to be necessary (Jaffe et al., 2005). Thus, the global diffusion of climate technologies also depends on the international diffusion of climate and technology policies (Beise & Rennings, 2003).

Due to the ongoing process of technological change, some climate technologies are still relatively new or even actively being developed, this means that in addition to transferring them horizontally (to new country markets), they must often simultaneously be transferred vertically (to new stages in the R&D process) (Ockwell et al., 2010). This makes the horizontal transfer process more complicated, since there are fewer experiences to draw from and the adaptations that must be made to accommodate new regional conditions are necessary on top of those changes that accompany the normal progress from research to final deployment of a technology. This includes the creation of economies of scale and the discovery of more efficient processes, all of which usually take place only after a technology has been on the market for some time. Since these benefits cannot be drawn upon for the newest of technologies, they are often associated with higher costs and higher risks, making their transfer and adoption more difficult (Ockwell et al., 2010).

It therefore becomes clear that the transfer of climate technologies is subject to very different motivations and incentives than the transfer of other types of technology. Usually, market forces are responsible for encouraging technology transfer with a reasonable degree of efficiency, since the time horizon of the transfer is primarily determined by the pressures of supply push and/or demand pull factors. With climate technologies, however, there is a global incentive to transfer them as quickly as possible to combat the threats of climate change (Ockwell et al., 2010).

2.2 General Trends in the Global Diffusion of Climate Technologies and Climate Innovation Capacity

Before summarizing general trends in the global diffusion of climate technologies and climate innovation capacity, a classification of climate technologies which will be used in the further analysis is presented in Annex 1. The classification starts from different fields of application for climate technologies, e. g. energy supply, and then distinguishes between different technology areas, e. g. renewable energies. In most of the cases a technology area can be further broken down into different technologies, e. g. wind power. Application fields coloured in green are mitigation technologies and those coloured in blue are adaptation technologies.

Based on this classification, an analysis of transnational patent applications was conducted in order to gather information about the global diffusion of relevant technological knowledge. Patents are frequently used to measure the intermediate output of innovation activities. Patenting data usually show only minor disturbances over time by occasional changes of patent laws or by major court decisions. A particular strength of this indicator is that IPC codes are classified in much detail and in most cases allow a good match with the technologies presented in Annex 1. Disadvantages of the indicator are the different propensity to patent across sectors and the fact that inventions and innovations that cannot be patented are neglected (Kleinknecht, Van Montfort, and Brouwer 2002)

The results reported in Figure 1 are based on data on transnational patent applications at the European Patent Office in the periods 1993-1995 and 2008-2010 for the relevant IPC codes by applicants from OECD and Non-OECD countries. When relating these figures to the global energy related CO_2 emissions it becomes clear that the Non OECD countries' increase of climate related innovation activities could not keep up with the increase in the share of global energy related CO_2 emissions. The share of CO_2 emissions by Non-OECD countries has increased from 44% in 1992 to 61.7% in 2012, with a projected rise to well over 70% by 2035 (IEA, 2014), while the Non-OECD countries' share of global patents in climate technologies is small (6.8% for the period 2008-2010) and has only increased marginally over this same time frame. It becomes obvious that innovation activity in the field of climate technology is highly concentrated on OECD countries, which speaks for international technology transfer and technology diffusion as a possible solution for the global problem of climate change.

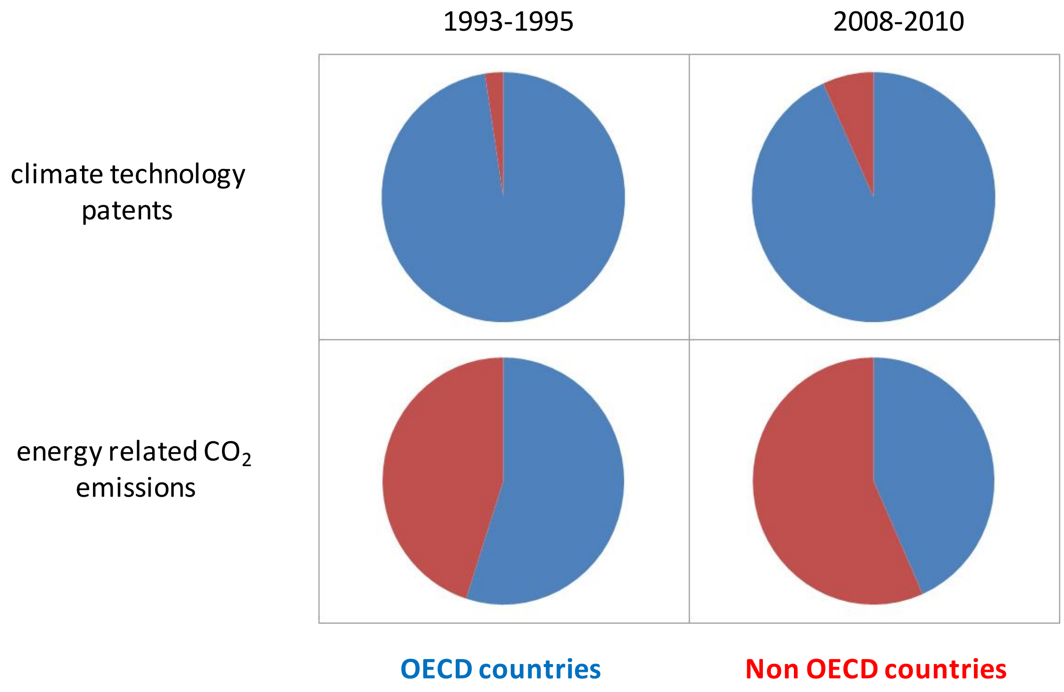

Figure 1: OECD and Non-OECD countries' share of international climate technology patents and energy related CO_2 emissions, based on EPO and the International Energy Outlook 2013 (Gandenberger, Peuckert, Christmann-Budian, & Bodenheimer, 2014)

In the following, some general trends in international technology transfer will be briefly discussed based on data on Foreign Direct Investment (FDI) and international trade with climate technologies.

Figure 2 shows that Europe is the by far the most important source and destination of FDI projects in renewable electricity generation. Europe and North America together attracted approximately 65 percent of global FDI between 2003 and 2010. However, the two regions 'South, East and South-East Asia' and 'Latin America and the Caribbean' attracted 15 percent and 9 percent respectively. Unfortunately, the publicly available data does not allow a more detailed analysis of global FDI in climate technology.

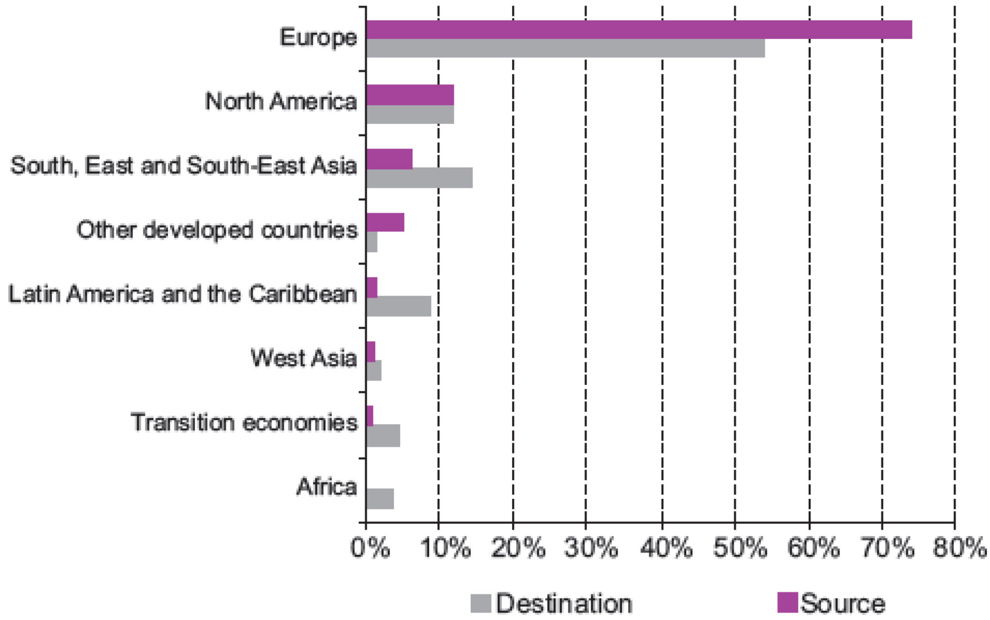

Figure 2: Renewable Electricity Generation FDI Projects, by Source and Destination Region, 2003-2010 cumulative, in percent of projects (Hanni, van Giffen, Krüger, & Mirza, 2011)

The three exemplary trade patterns for wind power equipment, photovoltaic and hydro power presented in figures 4-6 show that OECD countries mainly export to other OECD and high income countries, but there are some signs for a stronger involvement of upper middle, middle and lower middle income countries. The overall volume of trade has increased considerably between 1995 and 2010. For all three technologies, OECD exports to low income countries, lower middle income countries and upper middle income countries are far less important than exports to other OECD countries. However, with regard to wind power equipment there has been a considerable increase of exports from OECD to upper middle income countries starting from the year 2007. Similarly, with regard to hydro power, exports from OECD countries to upper middle and lower middle income countries strongly increased after the year 2005. When compared with wind and hydro power, OECD exports of PV equipment are much more concentrated on OECD countries.

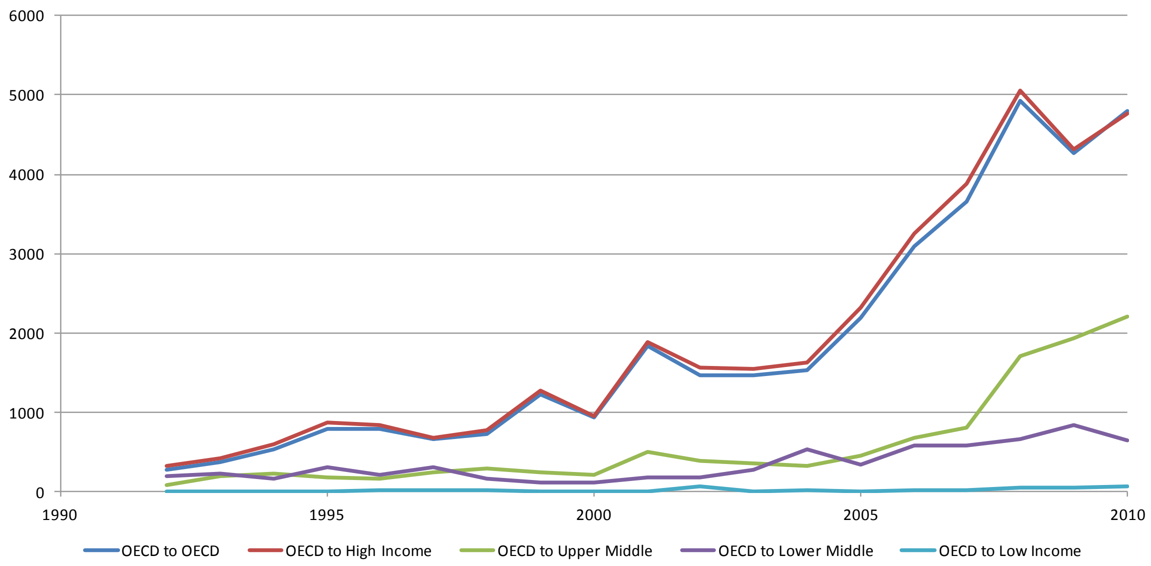

Figure 3: OECD Countries' Exports of Wind Power Equipment in Mio. $, based on UN Comtrade

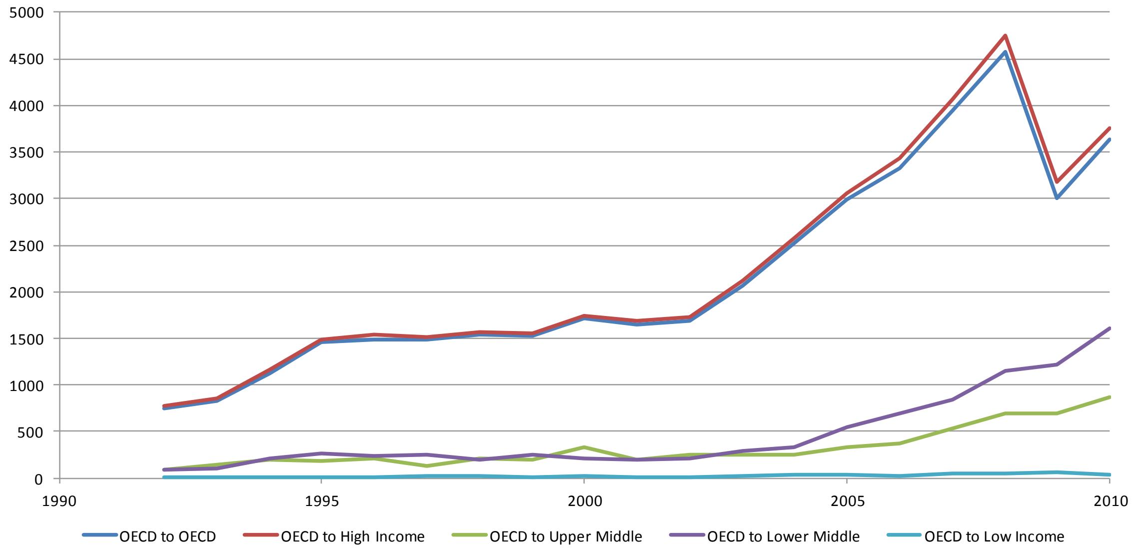

Figure 4: OECD Countries' Exports of Hydro Power Equipment in Mio. $, based on UN Comtrade

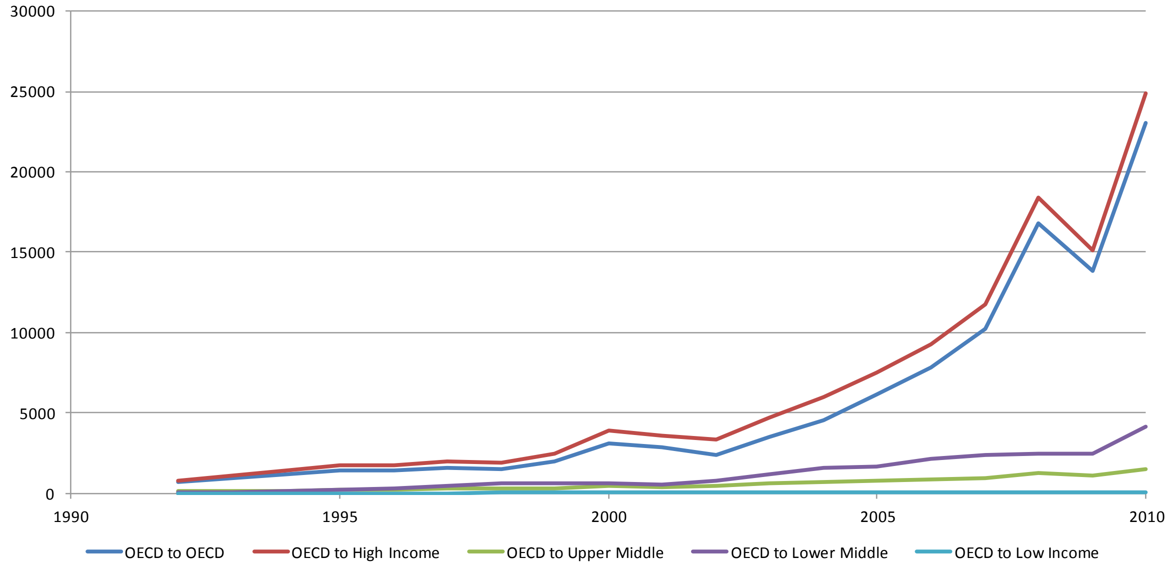

Figure 5: OECD Countries' Exports of PV Equipment in Mio. $, based on UN Comtrade

2.3 Mechanisms of International Technology Transfer

In spite of the important role played by international technology transfer in current global debates, there is no universally accepted definition of technology transfer (Popp 2008). Following the IPCC, we understand technology transfer as "a broad set of processes covering the flows of knowledge, experience and equipment...amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/educational institutions...The broad and inclusive term "transfer" encompasses diffusion of technologies and technology cooperation across and within countries...It comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions" (IPCC 2000, 3).

Although there are different opinions on how much knowledge must be passed along for technology transfer to take place (Haites et al. 2012; as cited in Ockwell and Mallett 2012, 166), this definition is appropriate for this study since it is concerned not only with developing countries' ability to use new climate technologies, but also their ability to adjust them to local conditions and implement the necessary means of production, as the overarching goals of the

UNFCCC require widespread diffusion of these technologies to be realizable. Moreover, ITT also represents a development opportunity for developing countries (Morgan and Waskow 2013). Incorporating new technologies into their repertoire, beyond accomplishing environmental goals, also allows developing countries to make progress in their technological and economic development through the learning and innovation processes that accompany successful ITT.

In order to narrow down the scope of our analysis, we examine only the transfer of hardware and the knowledge pertaining to the production, replication, adaptation and usage of this hardware, which excludes knowledge that is transferred in the form of services (such as reforestation projects, for example). Different transfer channels can be discerned:

- Trade is one of the most important channels by which embodied technological knowledge is transferred across countries. Imports of intermediates or capital goods can improve domestic productivity because embodied technology allows firms to employ more efficient production processes. Keller (2004) points to the fact that international technology transfer via trade is limited because knowledge becomes available only in its embodied form.
- Licensing involves the purchase of production or distribution rights for a product and the underlying technical information and know-how for producing it (World Bank 2008, 121). Licensing can be a substitute for FDI if uncertainty about the target country's political environment prohibits MNE to exploit the technology themselves. A good IPR protection will shift incentives toward licensing (Maskus 2002).
- FDI can contribute to technology transfer by investments in new machinery and equipment but also by R&D conducted in subsidiaries of MNE. According to World Bank figures for the year 2003, the share of foreign affiliates in total private R&D expenditures was well above 15 percent in Hungary, Brazil, Lithuania, Thailand, China, Argentina, Latvia, Poland and the Slovak Republic (World Bank, 2008, p. 117).
- Contacts with highly skilled diaspora members and other information networks, e. g. academic networks.
- One transfer channel that is specific for climate technologies is the Clean Development Mechanism (CDM) which allows developed countries to meet their national emissions targets using emissions reductions achieved through specific projects in developing countries. While it is not one of its explicit goals, the CDM is frequently perceived as a vehicle for international technology transfer (Dechezleprêtre, Glachant, & Ménière, 2008, 2009; Murphy, Kirkman, Seres, & Haites, 2013; Popp, 2011; Schneider, Holzer, & Hoffmann, 2008; Weitzel, Liu, & Vaona, 2014)

Teece (1977) has pointed to the fact that international technology transfer induces costs, on average 20 percent of total project costs. One reason for the high relevance of transfer costs is that only the broad outlines of a technology are codified, whereas the remainder is tacit. Tacit knowledge can only be passed on from person-to-person. The most effective way to do this is face-to-face interaction.

3 Framework for the Analysis of International Technology Transfer and Diffusion of Climate Technologies

This chapter develops and uses a simple conceptual framework for the analysis of international transfer and diffusion of climate technologies. The framework draws on theoretical approaches and literature on the internationalization of the firm, transfer channel choice and knowledge spillovers. The objective of this framework is to relate extant theoretical approaches on the firm-level and the country-level to each other and to elaborate on implications for the international transfer and diffusion of climate technologies. In a first step, the framework will be developed. Next, different theoretical approaches will be presented and discussed in order to illuminate crucial elements of the framework.

3.1 Introduction to the Framework

The conceptual framework presented in Figure 6 includes four interacting elements which are assumed to be crucial for the understanding of the international transfer and diffusion of climate technologies. The construction of the framework was guided by the following key questions:

- What drives some climate technology firms to enter foreign markets whereas others stay domestic?
- Which factors influence the mode of entry into a foreign market?
- Which factors influence the extent of spillover effects and technology diffusion in the foreign market?

Each of these questions have been addressed by different strands of the economics and management literature, i. e. the literature on international business, the literature on strategic management, and the literature on spillover effects and global technology diffusion. Thus, the objective of this framework is twofold: First, it should offer at least a rough guide on how the different theoretical approaches can be related to each other. This task can be conceived as a first step in the process of building a framework for the holistic analysis of international technology transfer and technology diffusion. Second, based on the specific characteristics of climate technologies elaborated on in chapter 2.1, the theoretical approaches are applied to the issue at hand, i. e. the international transfer and diffusion of climate technologies.

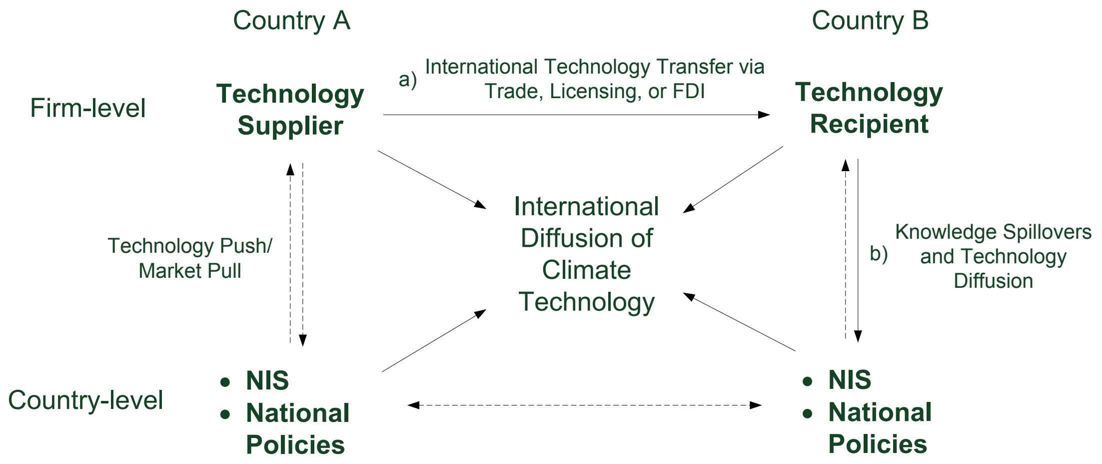

Figure 6: General Framework for the Analysis of International Technology Transfer and Diffusion of Climate Technologies

The framework consists of four elements that influence the international transfer and diffusion of climate technologies and their interactions and depicts a sequence of steps that are necessary for a climate technology to diffuse internationally. Analytically the framework differentiates between the transfer of a technology from country A to country B which takes place on the firm-level on the one hand and the diffusion of the technology within country B on the other hand. Technology diffusion starts at the firm-level after the technology recipient has successfully acquired the foreign technology. Then, the technology spreads to other actors of the National Innovation System (NIS) in country B, both in the form of technological hardware and in the form of technological knowledge. Our focus on technology transfer and diffusion implies that the following parts of the framework will be illuminated in greater detail:

a) the interaction between technology supplier and recipient on the firm level (international technology transfer) and

b) the interaction between technology recipient and the National Innovation System (NIS)/political framework of country B (technology diffusion or intranational technology transfer)

The importance to distinguish between interaction a) and b) is underlined by the finding that the rate of domestic technology diffusion for G-5 countries has been estimated to be about 200 times the size of the average rate of international technology diffusion (Eaton & Kortum, 1999). Interaction a) is assumed to be the main mechanism to transfer technologies from country A to country B. Our objective here is to develop a better understanding of the internationalization behavior of climate technology firms, because a certain degree of international activity of the climate technology firm is a prerequisite for technology transfer to happen.

The distinction between technology supplier and recipient does not necessarily refer to different companies, rather technology transfer can take place within the same company, e. g. from the parent company to a foreign subsidiary. Apart from International BusinessTheory, different approaches to the Theory of the Firm will be used to illuminate the different aspects that shape this interaction and to identify factors that influence the international transfer of climate technologies.

As mentioned above, interaction b) encompasses the diffusion of technological hardware and knowledge spillovers in country B. It is argued here, that the design of interaction a) influences the extent of knowledge spillover that is generated in country B, because transfer channels differ in their ability to transfer firm-specific tacit knowledge components which are often regarded to be crucial for the full mastery of a technology. Furthermore, the choice of an inappropriate transfer channel can influence technology diffusion negatively because of the higher costs that have to be incurred by the technology. Furthermore, the domestic technology diffusion hinges on national market creation policies and on the performance of the country's NIS.

In contrast to interaction a) and b), the interaction between the NIS / political framework in country A and the technology supplier will not be elaborated on here in greater detail, because the starting point of our analysis is a climate technology that has already been brought to the market in country A. This naturally does not presume that innovation processes in country A which aim at the further improvement of the technology and product differentiation have come to an end.

Moreover, the interaction between A and B on the country-level which encompasses bilateral cooperation between actors of each country's NIS, e. g. collaborative research between universities, research organizations or scientists, as well as cooperation in the field of climate technology, such as e. g. conducted in the context of official development aid, will not be pursued deeper in the following.

3.2 Firm-level Theories about Internationalisation and Transfer Channel Choice

3.2.1 Internationalisation of the Firm

3.2.1.1 Uppsala Internationalisation Model

The Uppsala Internationalisation Model (Johanson & Vahlne, 1977) is based on the behavioural theory of the firm (Cyert & March, 1963) and Penrose's theory of the growth of the firm (Penrose, 1959). The model conceptualises the internationalisation of the firm as a an incremental and self-reinforcing circular process that "... evolves in an interplay between the development of knowledge about foreign markets and operations on one hand and an increasing commitment of resources to foreign markets on the other" (Johanson & Vahlne, 1977, p. 11). Building on insights from the behavioural theory of the firm, the model describes the firm's internationalisation process as the result of a series of incremental decisions. Consequently, Johanson's and Vahlne's model is concerned with common traits or characteristics of the internationalisation process that are shared by successive decisions taken by the firm (Johanson & Vahlne, 1977). One of the model's basic assumptions is that a firm's lack of knowledge and international experience can constitute an important obstacle for the development of international activities and that the knowledge necessary for conducting international operations is created mainly through learning-by-doing, i.e. through operating internationally (Johanson & Vahlne, 1977, 1990). This assumption builds on Penrose's (1959) distinction between objective knowledge which can be taught, and experiential knowledge which can only be acquired through personal experience. Experiential knowledge is regarded to be of particular importance to operations in a foreign country. Whereas in domestic operations managers can rely on lifelong experiences, in foreign operations they have to build-up these experiences successively through operating in the country (Johanson & Vahlne, 1977).

The model is dynamic in the sense that present activities influence the firm's future decisions regarding internationalisation. Likewise, the outcomes of these decisions will influence the firm's future activities. Consequently, the model's structure distinguishes between “state aspects” and “change aspects”. State aspects capture the resources the firm has committed to the foreign market and change aspects reflect the firm’s current activities and decisions to commit resources to foreign operations.

State aspects

State aspects are further subdivided into the two concepts “market commitment” and “market knowledge”. Market commitment reflects the amount of resources committed to the foreign market and their degree of commitment. Whereas the amount of resources simply reflects the size of investment in the market, the degree of commitment is very similar to the concept of asset specificity as used in Transaction Costs Economics. It reflects the difficulty to find alternative uses for the resources that have been invested in a particular market. For example, an activity that is highly integrated with other operations of the firm would be more difficult for the firm to sell then a financial investment. The second state aspect, market knowledge, is highly relevant for international operations because commitment decisions are based on knowledge about market opportunities as well as the ability to judge opportunities and risks of foreign operations. As already mentioned, market knowledge is acquired mainly through personal experience from current business activities in a foreign market. As market knowledge accumulates, it acts as a “driving force“ in the internationalisation process (Johanson & Vahlne, 1990, p. 12). However, one has to keep in mind that market knowledge is very country specific.

Change aspects

Change aspects are divided into “current activities” and “decisions to commit resources to foreign operations”. Current activities are regarded as the most important source to gather experiential market knowledge. Moreover, as current activities consume financial and other resources of the firm, their level and duration strongly influences the firm’s commitment to the market. Commitment decisions are made in response to perceived problems and opportunities in the foreign market. These problems and opportunities will be identified mainly by those individuals of the firm that are responsible for the foreign operation. Thus, their knowledge and experience is highly relevant for making commitment decisions.

From the interplay between state and change aspects it follows that the internationalisation process of the firm can be understood as a sequence of incremental steps. However, Johanson and Vahlne (1990, p. 12) point to three exceptions from this rule. First, firm with large and surplus resources can make larger internationalization steps. Second, in stable and homogeneous markets, market knowledge does not necessarily stem from personal experience but can also be gathered from other sources. Third, when the firm has vast experience from similar markets these can be generalized to the specific market.

The Uppsala Internationalisation Model claims to be able to explain patterns in the internationalisation process of the firm (Johanson & Vahlne, 1990). The first pattern is that a firm's engagement in a foreign market develops in a certain sequence of steps, i. e. at the beginning there are no regular exports to the country, then exports are supported by independent sales agents, later through a subsidiary, and eventually the company invests in manufacturing. As the firm's foreign operation develop along this chain market commitment increases. Likewise, the firm's opportunity to gather experience and knowledge about the market is augmented with increasing engagement in the country. The second pattern explained by the model is that firm's enter new markets with successively increasing psychic distance. Psychic distance encompasses factors such as differences in language, culture, political system, etc.

3.2.1.2 OLI Paradigm

The OLI[1] Paradigm is the dominant theoretical framework to explain the extent, geography and industrial composition of foreign direct investments (FDI) and other foreign activities undertaken by multinational enterprises (MNE) (Dunning, 2000). Regarding the firm's motivation for FDI, four main types can be discerned (Dunning, 1998):

- *Market seeking* or demand oriented FDI strives to satisfy a particular foreign market or a set of foreign markets
- *Resource seeking* or supply oriented FDI is conducted to gain better access to the resources of a country, e.g. minerals or agricultural products
- *Efficiency seeking* FDI has the objective to bring about a more efficient division of labour or specialization of an existing portfolio of foreign and domestic assets
- *Strategic asset seeking* FDI wants to promote or protect the existing ownership specific advantages of the investing firm in relation to its competitors

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1 Ownership, Location and Internalization

The market entry of a MNE into a foreign country induces added social, political, and economic costs vis-à-vis domestic competitors which have been termed as liabilities of foreignness (Hymer, 1976; Oetzel & Doh, 2009). Nevertheless, many MNE manage to outperform their domestic competitors based on advantages which arise from the interaction of three sets of interdependent variables, namely ownership (O), location (L) and internalization (I). The first variable, ownership, encompasses ownership-specific advantages of the MNE relative to other firms, in particular to those firms that are already present in the market in which the MNE seeks to invest. The greater the MNE's ownership-specific advantages vis-à-vis these domestic competitors are, the higher is the probability that it will engage in FDI. The second variable, location, captures the attractiveness of a country in terms of resource endowments that are critical to the value-added activities of the firm. The more these resource endowments favour a firm's presence in a foreign country, the higher is the likelihood of FDI to occur. The third variable of the OLI paradigm, internalization, considers the benefits of firm-internal transfers of intermediate products vis-à-vis market transactions or hybrids. The greater the benefits of internalizing cross-border intermediate product markets, the more likely is the likelihood of FDI to take place (Dunning, 2000).

Dunning (2000, p. 164) emphasizes that "the precise configuration of the OLI parameters facing any particular firm, and the response of the firm to that configuration, is strongly contextual." This context will typically reflect the economic and political situation of the investing firm's home country as well as of the country in which the firm seeks to invest. Furthermore, characteristics of the investing firm's industry and the nature of the industry's value-added activities will have to be taken into account. Moreover, firm-specific characteristics such as a firm's strategy towards FDI will have to be included as important context factors.

3.2.2 Transfer Channel Choice

Companies that want to enter a foreign market can choose between different entry modes, e. g. export, licensing, joint ventures or wholly owned subsidiaries.[2] The choice between different technology transfer modes, such as intrafirm

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2 In fact, the available variety of entry modes is in fact much larger, see e. g. Andersen and Gatignon (1986). In order to reduce the complexity of our analysis we will distinguish only between export, licensing, joint ventures and wholly-owned subsidiaries.

transfer, licensing or market transfer, can be paraphrased as the choice between different boundaries of the firm. The analysis of boundary decisions lies at the heart of the theory of the firm (Foss 1996), which is why in the following we will draw upon transaction cost economics and the knowledge-based view as two alternative approaches towards the theory of the firm. Both approaches have been applied to the research about international technology transfer. Since the early publications of Oliver Williamson (1975), transaction cost economics has been the dominant research paradigma for analyzing boundary decisions of the firm. In a nutshell, the conclusions of this research are that boundary decisions are particularly influenced by the specificity of assets involved in the exchange (Foss 1996; Poppo and Zenger 1998). However, transaction cost economics has been challenged by the knowledge-based view of the firm (Grant 1996, Kogut & Zander, 1992; Conner 1991), which states that an intrafirm coordination of activities can posses unique advantages over market transactions which are not sufficiently explained by the risk of opportunism or moral hazard. Here, we will follow the advice of Foss (1996), who posits that with regard to questions pertaining to the boundary of the firm, the knowledge-based perspective can act as a necessary complement to the transaction cost perspective.

3.2.2.1 Transaction Cost Economics

In a nutshell, TCE states that there are fundamental differences between market and intrafirm exchanges in terms of the efficiency of different types of transactions. Transactions are defined as occurring “when a good or service is transferred across a technologically separable interface” (Williamson, 1981, p. 554). Because human behavior is characterized by bounded rationality and opportunism, transactions conducted in the market place are not free of cost. Instead, agents accrue search and information, bargaining, and/or policing and enforcement costs (Menard & Shirley, 2008; Voigt, 2009) in their attempts to find the desired good and acquire it under the most favorable conditions. As a result, Williamson posits that market transactions can – depending on the specific characteristics of the transaction – be more expensive than intrafirm transactions. These characteristics therefore determine the degree of organizational interaction that will be most efficient, ranging from a market, or arms-length, interaction to an intrafirm (hierarchical coordination) interaction. With these assumptions in mind, transactions are then evaluated along three dimensions:

- asset specificity;
- frequency of the transaction; and

- uncertainty surrounding the transaction (Williamson, 1981).

Asset specificity is considered the most important of these three aspects and is defined as the "ease with which an asset can be redeployed to alternative uses and by alternative users without loss of productive value" (Williamson, 1991, pp. 79–80). The greater it is, the more likely is an intrafirm exchange, since both buyer and seller are dependent upon each other to a great degree: assuming constant uncertainty and repetition of the transaction, market exchange is favorable for non-specific assets, bilateral contracting is preferable for semi-specific assets and internalization is the best option for highly specific assets (Williamson, 1981). Williamson argues that the key aspect of asset specificity is that it locks both parties to a transaction in, as the seller cannot easily find another buyer, nor can the buyer find another seller on equally favorable terms (Williamson, 1981, p. 555).

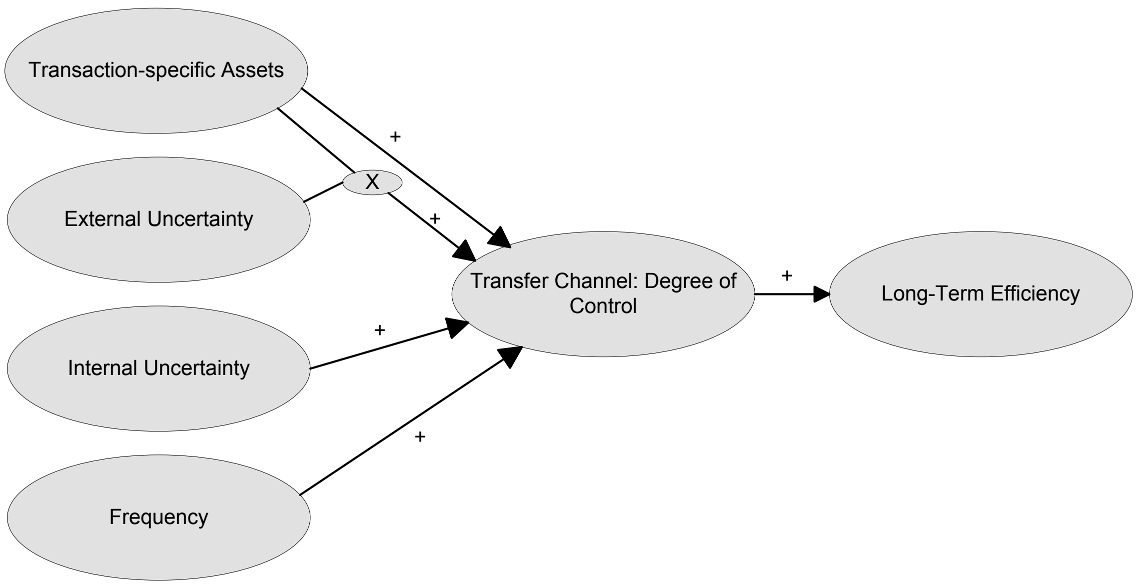

Figure 7: Transaction Costs Framework for Analyzing the Choice of Transfer Channel (based on Anderson & Gatignon, 1986)

With regard to frequency, Klein (2006) distinguishes between three types of frequency found in the literature: 1) the frequency of trade between specific trading partners; 2) the frequency of trade among many trading partners; and 3) the frequency of disturbances in the environment. With regard to the second type, which is of importance here, Williamson states that, first and foremost, specialized governance structures are most beneficial when asset specificity is high. However, in addition to this factor, the question arises "whether the volume of transactions processed through a specialized governance structure utilizes it to capacity […]. The cost of specialized governance structures will be easier to recover for large transactions of a recurring kind" (1985, p. 60). The frequency of interactions, even among different trading partners, is thus a relevant consideration with regard to the investment in specialized, i.e. hierarchical, governance structures. Finally, the preferable amount of organizational interaction is determined by the degree of uncertainty surrounding a transaction.

Anderson and Gatignon distinguish between external and internal uncertainty. External uncertainty is defined as "the volatility (unpredictability) of the firm's environment", often also termed "country risk" in the international context (1986, p. 14). Here, too, asset specificity plays a significant role in how uncertainty should be handled. If asset specificity is low while external uncertainty is high, the authors advise the avoidance of ownership, since it reduces flexibility and binds the firm to an environment that may no longer be as desirable after an environmental shift occurs. If asset specificity is high, on the other hand, flexibility is already strongly reduced given the dependence on a particular partner, leading to the conclusion that "given some degree of asset specificity, control becomes more desirable as uncertainty increases" and ownership thus becomes a progressively more attractive option (Anderson & Gatignon, 1986, p. 14).

Internal uncertainty "exists when the firm cannot accurately assess its agents' performance by objective, readily available out measures" (Anderson & Gatignon, 1986, p. 15). Internal uncertainty plays a particularly relevant role in the international context. The authors posit that, from a transaction cost perspective, a firm's degree of control in a foreign firm should increase with its international experience, as this leads to greater confidence in foreign markets. However, they concede that this statement may not apply in non-competitive industries, where the inefficiencies that stem from ethnocentrically motivated demands for control are not immediately extinguished by market pressures (Anderson & Gatignon, 1986, pp. 16–17).

3.2.2.2 Knowledge-based View

One of the most fundamental assumptions of the transaction cost approach is that markets and hierarchies are alternative governance modes which can, in principle, act as substitutes for each other. Following from the behavioural assumtions of the transaction cost approach, the choice of the most efficient governance mode is determined by the characteristics of the transaction and in particular by the specificity of the assets involved. In contrast to this perspective, other researchers have advanced the view that intrafirm transactions are not merely substitutes for market-based transactions in situations characterized by a high risk of opportunistic behavior, but also posses unique advantages in certain kinds of situations (Moran und Ghoshal 1999)

As an alternative to the view of the firm as an efficient contractual entity, firms can be described as "repositories of knowledge" (Dosi, Winter, und Teece 1992) that posses superior qualities with regard to the internal creation and transfer of knowledge (Kogut und Zander 1993). Advocates of this knowledge-based approach, which has evolved from resource-based and evolutionary theory, posit that persisting differences in the performance of firms can be ascribed to differences in the way productive knowledge is created and put into use (Foss 1996). Continued superior performance is believed to result from knowledge that is unique, difficult to imitate and able to generate output that is valued by the market (Grant 1996).

Knowledge is frequently subdivided into explicit and tacit knowledge. Tacit knowledge refers to the fact that people know more than they can explain (Polanyi 1966). This has important implications for the transfer of knowledge: whereas explicit knowledge can be easiliy codified and transfered, tacit knowledge is difficult to codify and closely tied to individuals or the teams that posses this knowledge. Based on tacit forms of knowledge, firms can build unique and path-dependent capabilities that form the basis for continued survival and growth (Penrose 1959). According to Kogut and Zander (1992, 384) "the central competitive dimension of what firms know how to do is to create and transfer knowledge efficiently within an organizational context." From the knowledge-based perspective, the growth of firms results from the fact that new knowledge is created by the organization or existing knowledge applied to new uses. Regarding the transfer of highly specific tacit knowledge, intrafirm coordination is believed to be the most efficient transfer mode because of the codes, language and routines that are shared by the members of the organization (Grant 1996).

Against this background, technology can be viewed as firm-specific knowledge that consists of explicit and tacit components. The former is codified in blueprints, designs, drawings and specifications, while the latter is tied to individuals and teams. In general, it can be said that the greater the extent to which a technology exists in the form of physical resources, the smaller the content of tacit knowledge (Tsang 1997). The application of existing technological knowledge to new uses frequently requires a transfer of this knowledge within or across organizational boundaries. However, such a transfer is associated with transfer costs which, in turn, are significantly influenced by the sender's experience with prior transfers, by the sender's experience with the technology, by the skills and experience of the receivers and by the characteristics of the technology itself (Teece 1976).

Technological characteristics, in particular the relevance of tacit knowledge, have been hypothezised to influence the choice of the technology transfer mode (Tsang 1997; Stock & Tatikonda, 2000; Hakanson/Nobel 2000). For example, Tsang (1997) argues that the tacit components of the relevant technological knowledge have to be transferred through close human interactions, which often requires a joint-venture or a wholly-owned subsidiary as transfer mode. Building on earlier research, he states that the relevance of tacit knowledge depends on the age and complexity of the technology. The newer and complexer a technology is, the more firms will favor an intrafirm transfer, e.g. to a wholly-owned subsidiary or joint venture. In a related approach, Stock and Tatikonda (2000) try to match the degree of uncertainty associated with the technology and the degree of organizational interaction between technology source and recipient. According to the authors, the degree of technological uncertainty is influenced by novelty, complexity and tacitness of the technology. Agreeing with the work of Tsang (1997), they state that high technological uncertainty should coincide with a high degree of organizational interaction, whereas a low degree of organizational interaction, e. g. arms-length market transfer, is recommended for technologies with a low degree of uncertainty.

Some researchers posit that the benefits that a firm can gain from technology transfer and the risk of imitation of the technology by competitors pose a fundamental dilemma for the firm (Winter 1987; Kogut und Zander 1992; Hakanson 2000). On the one hand, the existence of tacit knowledge components can increase the costs of technology transfer due to the necessary investments in transfer modes that are characterized by a close organizational interaction and the administrative costs associated with hierarchical coordination. From this perspective, it would be desirable to reduce the relevance of tacit knowledge for the technology. On the other hand, tacitness can act as a safeguard against imitation by competitors and stabilizes the rents which can be appropriated from the technology in the future.

3.3 Knowledge Spillover and Technology Diffusion on the Country-level

In line with the discussion in chapter 3.1 the following chapter distinguishes between knowledge spillover and technology diffusion in country B. This distinction is important for several reasons:

- Knowledge spillover is a by-product of international economic activity in the recipient country (Keller, 2004). It is, however, not the objective of the transaction between technology supplier and recipient. Technology diffusion, in contrast, refers to the increasing availability of technological hardware in the country and can be conceived as the direct result of the transaction between technology supplier and recipient which includes the transfer of knowledge in its embodied form.
- As soon as the recipient country has attained full mastership of the technology, technology diffusion may result exclusively from the increased production of domestic firms. Thus, unlike knowledge spillover, some sort of interaction between foreign and domestic firms is not a prerequisite for technology diffusion to happen.
- Whereas the generation and utilization of spillover effects is conditional on learning efforts on the part of the technology recipient, the diffusion of technological hardware does not necessarily require such efforts.

The distinction between knowledge spillover and technology diffusion has also important implications for policy making on the country-level which will be elaborated on deeper in chapter 4. Prior to that, we will turn to the findings of the extant literature on knowledge spillover emanating from trade and FDI.

3.3.1 Knowledge Spillover from Trade

Given the focus of our analysis, the following chapter will concentrate on the extant research on spillover effects from imports. Importing is associated with technology spillovers based on two effects (Keller, 2004):

- diffusion through embodied technology in intermediate goods
- other technology diffusion associated with imports

In one of the most seminal papers on the topic, Grossman and Helpman (1991) posit that productivity depends in part on a country's 'stock of knowledge capital', which can accumulate in two ways: through local research and development and through spillover from international contacts. The authors hypothesize that knowledge spillover is neither automatic nor instantaneous, but rather correlated to the number of contacts actors from an economy have to international research and business communities. Because these contacts grow with increased trade, it follows that knowledge spillovers increase in an open economy.

Coe and Helpman (1995) also build on the work of Grossman and Helpman, but they take a broader view on how knowledge is exchanged. Rather than focusing on contacts between individuals, they examine the relationship between the impact of domestic and foreign R&D efforts on a country's total factor productivity (TFP). They argue that innovation and cumulative R&D are related through a continuous feedback loop, where cumulative R&D leads to new innovations, which in turn increase cumulative R&D. Cumulative R&D expenditure is used as a proxy for stock of knowledge, which is presumed to be positively correlated to a country's ability to absorb new foreign technologies. Looking only at OECD countries (plus Israel), the authors find that for smaller countries, foreign R&D capital stocks (of their trading partners) may be even more important in determining TFP than domestic R&D capital stocks. Larger countries (the G7) instead see a more significant effect from domestic R&D capital stocks. Moreover, the foreign R&D effects are greater, the larger the share of domestic imports to GDP. Finally, productivity levels of a country are higher if the primary trading partners have high levels of technological knowledge than if they have low levels.

Using counterfactual international trade data, Keller (1998) re-examines the results of Coe and Helpman. He finds that the effects of foreign R&D on international R&D spillovers through trade are even larger when using counterfactual, randomly created bilateral import shares and argues that on this basis, "the composition of imports of a country plays no particular role in estimating a positive and significant [impact] from foreign R&D on domestic productivity levels" (Keller, 1998, p. 1479).

In response to Keller (1998), as well as a number of other critiques of the original study (Engelbrecht, 1997; Lichtenberg & van Pottelsberghe de la Potterie, 1996)[3] Coe, Helpman and Hoffmaister (2008) revisited the original study published in 1995, expanding both their methodology and their data set. While their re-examination led to small changes in values, their overall conclusions are quite similar to the original results. Moreover, they report "robust evidence of cointegration between total factor productivity, domestic R&D capital, foreign

3 For a detailed review of responses to Coe and Helpman (1995), see Coe, Helpman, and Hoffmaister (2008).

R&D capital based on a number of definitions, and a measure of human capital" (Coe et al., 2008, p. 4), which had not been considered in the original work.

In addition to re-examining their original work, Coe et al. (2008) also examined the impact of certain institutions on the degree of R&D spillovers. They ranked the countries in their study (OECD members as of 2004 plus Israel) in groups of high, middle, or low based on indicators for the ease of doing business as well as the quality of tertiary education. Their findings show that for both indicators, countries in the upper-third of the sample benefited more from domestic and foreign R&D, as well as deriving a greater return from investment in human capital than did countries in the other two groups. In fact, there was no benefit at all from international R&D spillovers for countries in the bottom third of the business indicator and the bottom two-thirds of the education indicator.

Further research has identified the relevance of imported capital goods which account for about 10 percent more of the variation in the recipient country's productivity than overall trade (Xu & Wang, 1999). Furthermore, Sjöholm (1996) identified a positive correlation between Swedish patent citations and bilateral imports.

In his review article on international technology diffusion, Keller (2004, p. 767) summarizes that "the evidence points to a significant role for imports in international technology diffusion. However, the various strands of the literature leave still some questions open, and we do not have yet a firm estimate of the quantitative importance of imports for international technology diffusion."

3.3.2 Knowledge Spillover from FDI

Knowledge Spillovers from FDI to domestic firms can emanate from various mechanisms, e. g. from workforce training and successive turnover, the integration into professional networks, the provision of high-quality inputs to the domestic industry or through contacts with local suppliers (Keller 2004 (Hale & Long, 2006)). The empirical evidence from a case study about Intel's FDI in Costa Rica suggests that there have been very significant positive spillover effects to the host country (Larrain, Lopez-Calva, & Rodriguez-Clare, 2000).

Econometric evidence points to the fact that productivity growth from FDI differs between sectors: High-technology sectors seem to profit more from FDI than low-technology sectors (Keller & Yeaple, 2003). Similar results are produced by a study among companies in Chinese cities by Hale and Long (2006) who find positive spillovers for technologically more advanced companies and no or negative spillover for more backward firms. They furthermore found that positive spillover effects result fully from two channels: labor mobility (managers moving from foreign-owned firms to domestic firms, thereby introducing new knowledge/skills to the domestic firms) and through networks among high-skilled worker.

Aitken and Harrison (1999) also try to explain where spillover effects come from, although they are focused more on the source of negative effects. Using a large sample of data from Venezuelan plants, they estimate log-linear production functions to compare the productivity levels of domestic and foreign-owned firms. Based on their results, they posit that positive spillover effects in their sample are largely endogenous: foreign firms invest in plants that are more productive to begin with and these continue to outperform those domestic firms which did not receive foreign investments. Moreover, they find that productivity for domestically-owned plants in fact decreases as foreign investment (in other plants) increases. To explain this, they propose a similar theory to the competition effect set out by Konings (2001), calling it the "market-stealing effect" (Aitken & Harrison, 1999, p. 606). The results from Konings (2001), who examines the spillover effects of FDI in Romania, Bulgaria and Poland from 1993 to 1997, are quite different from studies that focus only on industrialized countries. He finds that spillover effects from FDI in Romania and Bulgaria are actually negative and explains this with the 'competition effect', where domestic firms struggle to compete with their more advanced foreign counterparts. For Poland, he found no spillover effect, arguing that Poland is more advanced than Romania and Poland and therefore not as susceptible to the competition effect.

4 Implications for the International Transfer and Diffusions of Climate Technologies

4.1 Firm-level Implications

The most important implication that follows from the Uppsala Internationalization Model is that the international transfer of climate technologies will be an incremental, self-reinforcing process due to the nature of the underlying internationalization processes of climate technology firms. The development of foreign markets will likely follow a sequence of steps, e. g. starting from exports supported by independent sales agents, followed by exports through a subsidiary, and eventually the company invests in local manufacturing. Notable exceptions from this rule are firms with large and surplus resources that can make larger internationalization steps. Furthermore, firms operating in stable and homogeneous markets can gather market knowledge from other sources than personal experience. Moreover, firms that possess vast experience from similar markets can generalise these to the specific market.

Based on the Uppsala Internationalization Model the knowledge about foreign markets is of crucial importance for the internationalization process. Thus, the international diffusion of climate technologies will probably follow the diffusion of other products and technologies, because firms can draw on their existing market knowledge – a conclusion that is supported by the empirical data presented in chapter 2.2. This implies that climate related knowledge and equipment will not automatically diffuse to those countries and regions where they are in greatest need but rather follow existing patterns of international trade and FDI. Furthermore, climate technology firms will probably have to commit very specific resources when transferring their technology to a foreign market, because market demand for climate technologies frequently hinges on the receiving countries' regulatory framework and companies need to have a good understanding about the relevant regulation. This highlights the importance of highly qualified and experienced staff that is able to identify opportunities and risks associated with foreign markets.

Unlike the Uppsala Internationalization Model, the OLI paradigm is not a dynamic perspective on the process of internationalization but a rather static approach to analyze FDI and other international activities. Based on the patent data discussed in chapter 2.2, it is argued here, that ownership-specific advantages of climate technology firms from advanced countries vis-à-vis their competitors from more backward countries will likely be based on firm-specific technological knowledge. In its tacit form, firm-specific knowledge is typically embodied in the firm's engineering and technical staff as well as in the firm's R&D, product design, production and sales processes. Furthermore, explicit technological knowledge can be embodied in the firm's intellectual property, e. g. patents and blueprints. Following from the prescriptions of the OLI paradigm, the likelihood that climate technology firms will engage internationally is high because of their ownership advantage. In contrast, location advantage should not influence the likelihood of climate technology firms to invest in foreign production, because, in general, natural resources are of minor importance to the value-added processes of climate technology firms.[4] Internalization advantages arise when there are benefits from firm-internal transfers of intermediate goods vis-à-vis market transactions. Based on previous research, Markusen (1995, p. 181) arrives at the conclusion, that technology transfer is likely to be internalized "when the products are new, complex, have no prior commercial application, and are produced by R&D-intensive firms." Even though not all climate technologies will meet these criteria, some of the technologies presented in figure 9 show a considerable increase in patenting activity over the last years, e. g. wind power, hydro power, PV, heat pumps, or hybrid vehicles, suggesting that these technologies attract a high amount of research that will lead to frequent changes of the technological state-of-the-art. In such a situation, firm-internal transfers will have advantages over market-based transfers. However, other climate technologies, such as technologies for waste collection and treatment, experienced no or only marginal increases in patenting activity and can thus better be characterized as established and well-known technologies that presumably can be efficiently transferred via the arm's length market transactions.

All in all, the OLI paradigm would speak for a high likelihood of climate technology firms from advanced countries to engage in FDI in developing countries based on their ownership-specific technological advantages and advantages arising from firm-internal transfers.

From the viewpoint of the theory of the firm, the choice of the most appropriate transfer mode for a given technology is conceived as a decision about organizational boundaries. From what has been said above, it has become obvious that transaction cost economics and the knowledge-based view point to different attributes of the technology transfer process. Following Dunning's (2000) proposal that the OLI paradigm can act as an envelope for economic and business theories of MNE activity, both approaches to the theory of the firm are considered here as a complements to the OLI paradigm with respect to its internalization dimension and help to address the following question: how and under what circumstances can internalization advantages arise?

Whereas TCE views asset specificity as the most important reason for choosing an intrafirm transfer due to the risk of opportunism, the KbV instead emphasizes

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4 There might be exceptions from this rule, e. g. in the case of critical metals that are necessary for the production of some climate technologies, such as rare earth elements needed for the production of direct drive wind turbine generators.

the superior efficiency of intra-firm knowledge exchanges as compared to those that take place on the market. With regard to tacit knowledge, the transaction cost of a market transfer might be particularly high not because of the risk of opportunism, but rather due to the low efficiency or even non-existence of markets for tacit knowledge.

The argument presented here is based on previous research, which finds that the degree of tacitness of technological knowledge is related to the complexity and the dynamics of the technological knowledge-base (Tsang 1997; Stock and Tatikonda 2000; Tatikonda and Rosenthal 2000). It is argued that tacit knowledge in general is much more firm-specific than explicit knowledge, because it evolves over long periods of time within the boundaries of the organization and resides in teams and organizational routines, which are closely tied to the organization.

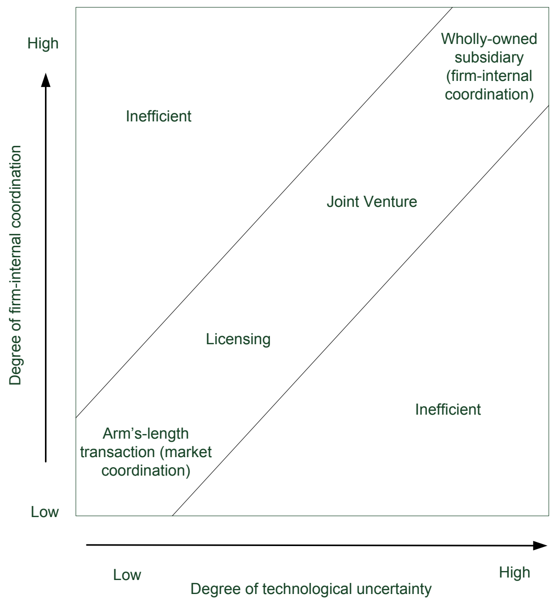

Figure 8: Relationship between the degree of technological uncertainty and the degree of intrafirm coordination (adapted from Stock and Tatikonda 2000)

Figure 8 portrays how the degree of uncertainty stemming from technological characteristics can be related to the degree of intrafirm coordination. Four different transfer modes have been selected, which show an increasing degree of intrafirm coordination: arm's length transaction, licensing, joint ventures and intrafirm transfer. These transfer modes represent the most efficient match between the uncertainty resulting from technological characteristics and the degree of intrafirm coordination. Arm's-length transactions are the most efficient transfer channel for technologies that are characterized by a low degree of technological uncertainty, whereas intrafirm transfers are recommended for technologies that have a very complex and dynamic knowledge-base.

These findings can be briefly summarized as such: If technology transfer involves firm-specific tacit knowledge, it follows from the KbV that these knowledge components can be more efficiently transferred within the boundaries of the firm, because intensive and trusting face-to-face communication between technology supplier and receiver is necessary. Furthermore, TCE analysis emphasizes that investments in the transfer of firm-specific tacit knowledge will be characterized by asset specificity. As a consequence of these bilateral investments, both parties of the transaction would become locked into the exchange, which results in a situation characterized by high uncertainty. As Davidson and McFetridge (1984) have pointed out, the transfer of newer and more complex technologies will increase measurement costs and the uncertainty surrounding the transaction. Keeping other influences on technology transfer constant, such investments will increase the uncertainty surrounding the exchange. Based on these considerations, advantages from internalization will likely be stronger if new and sophisticated technologies are involved. However, as TCE also points to the frequency and uncertainty dimension of the transaction, market size and the overall stability of the political and market framework will also be important aspects to be taken into consideration.

4.2 Country-level Implications

4.2.1 Country A

Given the double externality problem associated with climate technology innovation (see chapter 2.1), a combination of technology push and demand pull stemming from country A’s innovation and climate policy is considered to be necessary in order to support innovation activities taking place in domestic climate technology firms. Based on their technological advantage, technology suppliers from country A will engage in international market seeking activities and international technology transfer to country B.

At the first sight, knowledge spillover effects to country B’s are expected to successively decrease incentives for further innovation in country A because of the competition from domestic companies that drives prices for the technology down (Jaffe et al., 2005). Wang and Blomström (1992) show with help of a theoretical model that the degree of positive spillover depends on the host country firms' learning investment which can have a self-reinforcing effect. As the host country firms increase their stock of knowledge, the technology gap is reduced and foreign firms begin importing ever more advanced technologies to their subsidiaries, giving host country firms an opportunity to again increase their knowledge. Further improvements of the technology, increased technology diffusion and climate benefits are likely to result from these efforts. However, incentives for country A to further invest in climate technology innovation would probably be decreased if country A's companies would eventually lose their competitive advantage as the technological gap closes.

Keller (2004), however, has stresses the fact that technology transfer will always be incomplete due to the tacit nature of some knowledge components. As highlighted also by the KbV, tacit knowledge components are deeply embedded within organizational processes and technological staff of the firm and, thus, will be hard or even impossible to imitate. From this perspective it seems to be more likely that country B's companies will profit from spillover effects to some degree, but country A's companies would still be able to capture most of the profit from their innovation. In this scenario, country B's competitiveness vis-à-vis country A can only be increased through idiosyncratic innovation efforts and scale effects that arise from increased technology adoption and diffusion in country B. For example, idiosyncratic technological learning might take place through processes of learning-by-doing and learning-by-using. As competiveness of country B's climate technology companies eventually increases, prices for the technology will come down and global technology diffusion is enhanced.

4.2.2 Country B

With regard to country B, one major implication of the previous analysis is that the international transfer of climate technologies which as a group can be classified as medium to high technology goods might lead to spillover effects in the recipient country. However, there exists a considerable technological heterogeneity within the group of climate technologies. Some technologies, e. g. for waste collection, might probably better be characterized as low or medium technology goods; whereas others, such as PV, are high technology goods.

Following from the research on spillover effects, there is some general advice on how recipient countries can further the generation of spillover effects. Investments in R&D and human resources can enhance the ability of domestic firms to absorb technological knowledge emanating from foreign trade, licensing, or FDI. Furthermore, the quality of a country's institutions pertaining to the ease of doing business for foreign and domestic firms have been identified to be a driver for the generation of knowledge spillovers (Coe et al., 2008). Others have pointed to the importance of a well-functioning labor market which allows high-skilled workers to move quickly from MNE to domestic firms. In a more general stance, Keller (2004, p. 779) concludes that "while there is no consensus yet on the exact magnitude of spillover benefits, it is clear that well-functioning markets and an undistorted trade and foreign-investment regime are conducive to these learning effects."

This paper stresses the importance of an undistorted trade and investment regime for technology diffusion from a theoretical viewpoint, because it highlights that the choice, for example between trade and FDI, is subject to a couple of strategic considerations. As a consequence, restrictions on trade and/or FDI might result in choosing an inefficient transfer channel leading to higher technology costs or even evasion of the technology supplier to other country markets. The overall quality of governance is particularly relevant for the diffusion of climate technologies due to the strong influence of the state on the creation of market demand and on the regulation of the relevant infrastructures (e.g. energy, water, transport). In fact, some developing countries have tied their subsidies schemes for renewable energy to local content requirements (Rennkamp & Boyd, 2015; Gandenberger, et al., 2015). Even though the infant industry argument might provide some justification for such measures, their negative influence on climate technology diffusion and global actions on climate change has to be taken into account.

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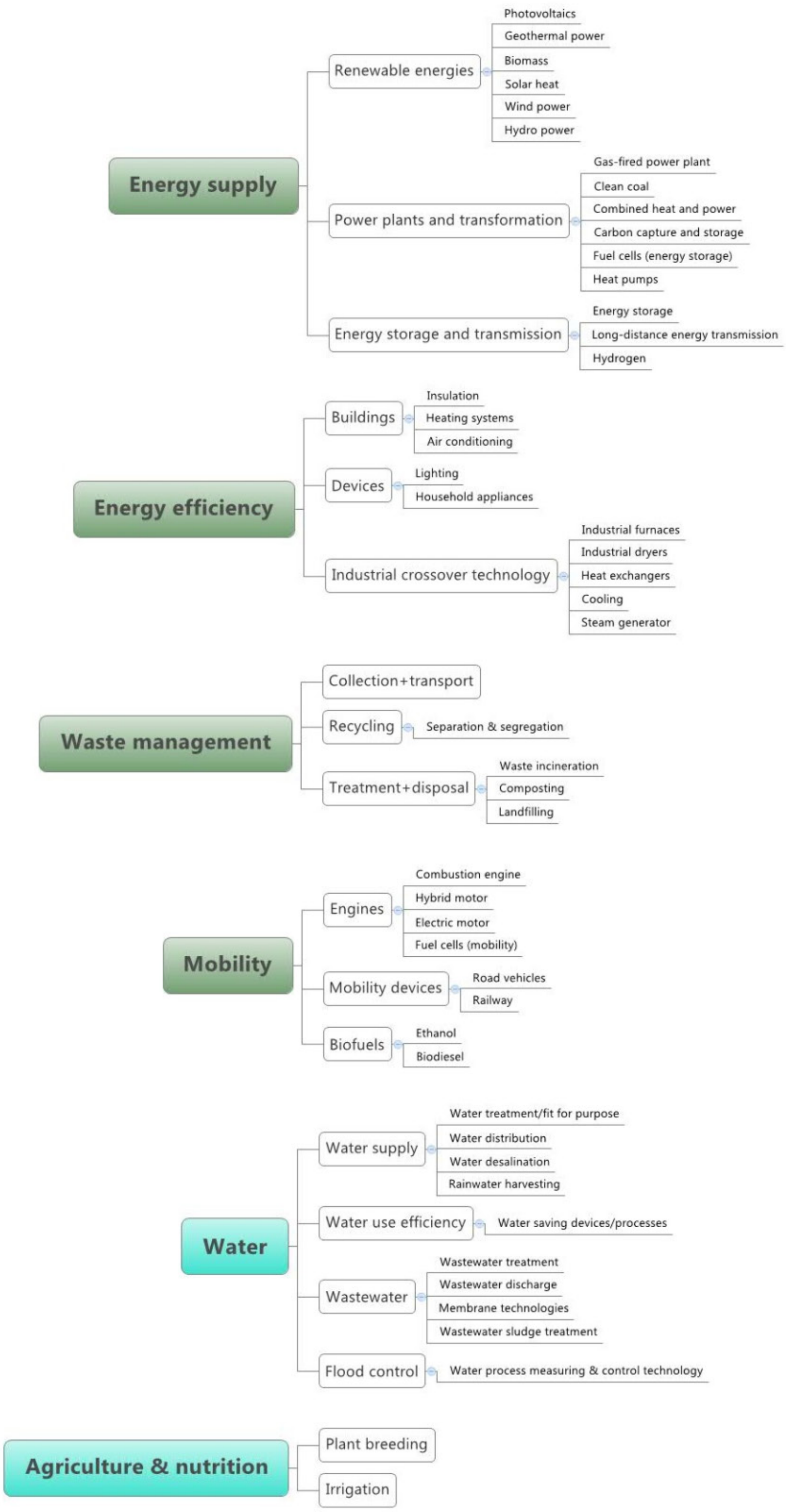
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