SPILLOVERS THROUGH IMPORTS AND EXPORTS

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Abstract

International trade is growing in importance and in real terms for many countries. As technology expands, so too does international communications which in turn can result in more knowledge spillovers. This paper explores the possibility that importing may not be the only means by which international knowledge spillovers occur. It analyzes international knowledge spillovers by examining the role of exporting as a mechanism for transmitting these spillovers. Unlike previous research this work pulls together both channels of international trade for transmitting knowledge spillovers.

This paper extends David Coe and Elhanan Helpman (1995) by examining the relationship between total factor productivity and the acquisition of productive knowledge and illustrating the importance of knowledge spillovers. This paper shows that for the OECD countries examined, including the United States, international knowledge spillovers are transmitted and received as a result of trade. Both importing and exporting facilitate knowledge spillovers but they are not identical. In this analysis, some countries receive and provide more productive knowledge spillovers than others. The production of new productive knowledge leads to an ever-increasing stock of knowledge and this capital stock is not national but international.

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1 Introduction and Literature Review

International trade is a frequent topic in the news. Concern over the benefits and costs of international trade are frequently discussed by a wide variety of people including newscasters and politicians. Many people want to know how international trade will affect their future. International trade is rising in importance as importing and exporting sectors of most countries grow. This growth is fueled at least in part by knowledge spillovers transmitted by the international flow of goods and services as firms forge contacts with rivals, potential rivals, and non-rivals in an attempt to gain an advantage or increase market share. It is through these international contacts that productive knowledge flows either explicitly as when a customer discloses proprietary knowledge to a subcontractor or implicitly. It is clear that both intraindustry and interindustry knowledge spillovers play a role in the innovation process. Total factor productivity is affected by the initial development of productive knowledge. Yet while the mechanism of transmission may be identical for imports and exports, the recipient industries are not identical as most industries are importers or exporters but not both. This paper will assess the impact of geography, international boundaries, and international relations on knowledge spillovers that occur as a result of international trade.

New innovations along with new methods of production are frequently the end results of research and development, but the accumulation of productive knowledge at a particular firm may not solely be due to that firm's own research and development efforts. As Griliches (1992) notes, much of the recent interest in knowledge externalities is in the area of changes in productivity. Productivity research is pursued on two very different levels. One looks at changes in the productivity of firms and industries, while another examines increases at the national level. The new economic growth theorists, such as Richard Levin (1998), focus on the role played by the accumulation of knowledge, and the subsequent knowledge spillovers this causes, in aggregate economic growth. At the same time, microeconomists such as Acs and Audretsch (1988) and Jaffe et al. (1993) focus their efforts on the effects of this unintentional knowledge transmission on the productivity of specific firms or industries. Their research focuses on the relationship between productivity gains and research spending.

The Micro-Foundations of Spillovers

A large number of studies investigate inter-firm, intraindustry spillovers of knowledge. Acs and Audretsch (1988) find that knowledge spillovers affect some recipients differently than others. They discover that the spillovers are more important to the innovation process in small firms than in large firms, when defining large and small firms as those with more or fewer than five hundred employees. The authors found that the majority of new inventions came from large firms in industries with high barriers to entry and high levels of concentration. Acs and Audretsch find that small firms are responsible for most of the innovation in industries with lower barriers to entry or lower levels of concentration. Noting this difference, the authors attempt to discover an explanation and to examine the process of innovation. Their model estimates the extent to which industry characteristics can affect innovative output and explores the reason for innovative differences between small and large firms. The authors discover that firms have different responses due to the market structure of industries and to distinct technological and economic stimuli. Their findings suggest that innovative output is affected not only by R&D but also by the market structure characteristics of an industry.

Once the authors discover that small firms are the basis for the majority of innovation in some industries, they then uncover how this might occur. Their discovery questions the general perception that the majority of research occurs in the largest industrial corporations. In a second paper by Acs et al. (1994), the authors uncover where small firms obtain most of their innovative inputs. Examining the inputs of inventive knowledge in large and small firms using a production function approach, the authors show that small firms benefit greatly from the knowledge spillovers from larger firms and universities. For smaller firms, a major and very important input in their knowledge production function is the spillovers they receive from other organizations. In larger firms, external knowledge spillovers are of less importance to the firm, presumably because firms are also receive internal knowledge spillovers illustrating the importance of scope economies. Small firms have a more limited base of research projects and are more dependent on information from external sources, while this is not true of the larger firms. The larger firms benefit from scope economies and internal knowledge spillovers from the variety of research projects they can support, so they are less dependent on knowledge spillovers.

Geography and International Spillovers

Jaffe et al. (1993) summarize the empirical findings of the past decade on knowledge spillovers, and note that while there is much research on knowledge spillovers, there has been very little research on where these spillovers might go. As Jaffe et al. point out, there are many policies devoted to increasing the United States' international competitiveness and all of these policies implicitly assume that there is a geographical component to knowledge spillovers. Additionally the results from knowledge accumulation can be localized within the United States', if not in a particular region. Jaffe and his co-authors attempt to empirically illustrate that there is some geographical component to knowledge spillovers.

Unlike spillovers at the industry level, at the national level there are many preconceived ideas about the existence and the welfare effects of knowledge spillovers. Early studies of knowledge spillovers implicitly assumed that knowledge spillovers were important within a nation but did not cross international boundaries. Clearly, this is not true. More recent research allows for international knowledge spillovers without clearly identifying the channels of this transmission and the costs of transmitting this knowledge.[1]

Park (1995) attempts to prove that spillovers of domestic governmental policy and knowledge are not geographically localized within national boundaries. To accomplish this, Park examines the effects of knowledge spillovers that occur at the global level as he assumes that knowledge spillovers transmit domestic policy and technological innovation to other nations. He also uses research spillovers as a measure of knowledge spillovers as he examines how the national stock of productive knowledge creates these flows of information and policy. It is through knowledge spillovers that Park believes national governments are able to influence other economies. In essence, he implies that these knowledge spillovers create government policy spillovers. Park uses OECD data in an input-output framework and a total factor approach to examine the international spillovers of knowledge and government policy. Empirically Park is able to show that knowledge spillovers are an important component of growth and total factor productivity.

Park is able to illustrate that international knowledge spillovers are more important for some countries than for others. This is partly because the majority of research occurs in a small number of countries. Most countries, except the United States, are like small firms, in that the external pool of knowledge and thus knowledge spillovers are more important than internal R&D in explaining the country's ability to innovate.

Bernstein and Mohnen (1998) empirically investigate the boundaries of knowledge spillovers. These authors use industry data from the United States and Japan to examine the extent of inventive knowledge spillovers to determine if these spillovers are predominantly localized within a country, or whether they occur across national boundaries. The authors note that with the growing importance of international trade, foreign direct investment, and the existence of international knowledge diffusion, there is also a growing interdependence of each nation's productivity growth. Thus, a nation’s growth is dependent not only on its own capital accumulation but also on knowledge capital accumulated by other countries. Bernstein and Mohnen show that international knowledge spillovers do occur and effect both economies in the short run and the long run through labor, intermediate inputs, R&D capital, and physical capital. The knowledge flows alter variable costs and factor intensities used in the production process; affecting both countries' research-intensive industries. Bernstein and Mohnen estimate that international spillovers between these two countries increase aggregate growth in Japan by sixty percent and in the United States by twenty percent. The difference is because knowledge spillovers have higher elasticities in the Japanese economy.

Grossman and Helpman (1991) investigate how the theory underlying comparative advantage and the gains from trade fits in quite neatly with our understanding of knowledge spillovers and growth. Grossman and Helpman set up a theoretical model that describes the relationship between endogenous growth, trade, and the accumulation of knowledge capital. Coe and Helpman (1995) in turn take this model and test it to analyze the importance of international knowledge spillovers by creating a single pair of elasticity coefficients. One coefficient measures the elasticity for domestic spillovers while the other measures international spillovers.

This paper follows from the empirical model build by Grossman and Helpman (1991) and tested by Coe and Helpman (1995), but it follows an approach more similar to Park (1995) in that it examines the empirical results for each country rather than the more comprehensive approach used by Coe and Helpman who aggregated across multiple countries to generate their elasticity coefficients. This paper examines domestic and international spillovers by country, looking at imports as well as exports as a mechanism for transmitting the spillovers. Challenging the assumptions made by other authors including Coe and Helpman, this paper examines whether imports and exports as mechanisms for transmitting international spillovers are identical or not. In the next section, this paper describes the theory, outlines the hypothesis, and describes the model used as well as the data. Section three describes the results and section four presents the conclusions on international knowledge spillovers and their channels.

2 Analysis

The Theory

To understand international knowledge transfers it is important to know the channels for that spillover. The studies by Grossman and Helpman (1991) and Coe and Helpman (1995) suggest that international trade, through imports, primarily transmits international knowledge spillovers. While Coe and Helpman examine the importance of imports on determining international contacts, this paper examines the relative impact of imports and exports. The channels for information acquisition include the disclosure of patents and interpersonal communication with suppliers, customers, and rivals. While Coe and Helpman focus on the flow from foreign suppliers to domestic customers, this paper also considers the flow from foreign customers to domestic suppliers. The channels of information include the interaction between foreign suppliers and domestic producers that frequently occurs in the general course of business. A foreign producer commonly reveals information about innovations to its customers as a sales tool. Interpersonal communication with rivals occurs through publications, technical or informal meetings with employees of other firms, and the movement of employees between positions. As noted previously in this paper, this less expensive acquisition of knowledge is generally not as effective as licensing technology, using reverse engineering on a product, or independent R&D. While considerably less expensive, it is not free, as transmissions of spillovers still require potential recipients to commit resources in order to learn about these knowledge externalities and to discover how to use them.[2]

At the same time, exporting to other countries can result in the inflow of technological knowledge gains, from the countries of origin to the destination country. When a domestic company exports goods to a foreign country the domestic producer often receives information concerning preferences of foreign customers. Additionally foreign regulations often come with shared technologies to assist the exporter with compliance. Moreover, the exporter will often work with foreign nationals, which may facilitate knowledge spillovers. By examining these potential channels of international knowledge spillovers, the importance of contact across and among international industries can be examined.[3]

The Hypothesis

This paper will show that information is not only transmitted across industries ; it is also transmitted across countries. Total factor productivity for a particular sector of an economy depends on research done within a nation's industries and from outside of that particular nation. These equations will look at the importance of the acquisition of domestic and foreign productive knowledge across all the sectors in a particular country for achieving increases in total factor productivity. These productivity gains, if any, appear in the industries of the nation being examined and consequently can affect the country's overall measured productivity. This paper examines the effects of intranational and international knowledge spillovers on the growth of each industry. The use of Coe and Helpman's method of modeling allows for the separating of the national and international sources of these spillovers and to determine the relative importance of each. This paper hypothesizes that increases in research and development in an industry in one country lead to increases in total factor productivity in both its domestic sector and in foreign sectors. For some countries the international flows will be statistically significant while for others they may not be as countries with more international trade in technologically similar, and in sophisticated industries, will more often receive significant international flows than other countries.

Using the model first developed by Grossman and Helpman (1991), this paper separates the effects of research and development upon total factor productivity into two different types. The first variable represents all R&D accomplished across each industry within a specific country and the other measure represents all productive knowledge acquisition done within each industry in the foreign economy. By breaking research and development into two different variables, this paper will attempt to show the importance of intranational and international knowledge flows to each country. This paper will also show that for many countries international knowledge flows are at least as important as intranational knowledge spillovers. This separation of the two different aspects of research and development is also important because the acquisition of international and intranational productive knowledge may have different effects upon the level and type of R&D within the national economy and the growth of the country's total factor productivity. Depending on the industry, more knowledge spillovers may be channeled through export channels than import channels. Coe and Helpman (1995) implicitly assume that knowledge spillovers from both sources are identical. This may not be true, so the model will also test to see if exports and imports provide identical channels for knowledge spillovers.

Furthermore, this paper will examine the importance of geographical and technological distance on international knowledge flows. Traditionally, knowledge has been described as diffusing across countries through trade and multinational corporations from the more advanced country to the less developed country. This allowed the less developed country access to the information of its more developed counterpart and gave firms within that country the chance to imitate their more successful foreign counterparts. This explanation assigns no role to geography since only technological distance matters. Examining the importance of geographic and technological distance on international knowledge flows will explain more about the localization of knowledge spillovers. Examining a country's relationships with neighboring countries will allow us to see if knowledge spillovers are geographically localized even when the spillovers happen to cross international borders and to determine the extent of this localization.

There is an important on-going relationship between each pair of the countries. The types of relationships are: historical, geographical, competitive, and economic. These relationships explain why contact between these nations arose. These foreign contacts in turn lead to business relationships that spread knowledge spillovers. A good example of an economic relationship built on the supply of a critical input is Japan's relationships with Canada and Norway. Since Japan has very few raw materials available domestically, Japanese firms turn to foreign producers. One input of great importance to these firms is oil. Norway is a large exporter of oil. Canada on the other hand exports many primary products and is a large oil refining country. Any knowledge flows about the conservation, new uses of oil, or product improvements would be of great value to Japanese firms.

Another relationship where the knowledge spillovers can be valuable is in a competitive relationship. An example of a very competitive relationship is the relationship between United States and Japan (or the United States and Switzerland) in pharmaceuticals. A geographical relationship occurs where two countries in close proximity have a continuous relationship due to that proximity. Examples of this geographical relationship exist between the United States and Canada where each country is the other's major trading partner or the relationship between Germany and the neighboring countries of France, Italy, Netherlands, and Switzerland. Other countries not in close proximity might still possess close ties due to shared history. Relations that fall into this category include the ones between Australia and Great Britain, Australia and the United States, and Canada and France.

Investigating the importance of technological distance, where producers use similar production processes or produce similar products, is also important because this traditional explanation of knowledge diffusion and knowledge flows explains little about the flows between more advanced countries. Bernstein and Mohnen (1998) show that there are knowledge flows between United States and Japan even though these two countries both have technologically advanced industries. In fact, much of the trade between industries is between technologically similar firms. Therefore discovering how much insight this traditional explanation of knowledge diffusion gives us about knowledge spillovers, could be interesting.

Empirical Model

When investigating the acquisition of productive knowledge by firms and industries within a country, Coe and Helpman (1995) examine the importance of foreign and domestic productive knowledge acquisition in their model. Based on the model used by Coe and Helpman, this paper employs more than one measure of R&D. The first research and development variable measures the acquisition of productive knowledge within a specific country while the other one measures all the research and development done outside of the country by a trading partner. In this model

$$TFP_t = \alpha_t^0 + \alpha_t^d RAD_t^d + \alpha_t^f RAD_t^f$$

where t is time.[4] In this specification of the model, TFP is the log of total factor productivity. The intercept term is the country specific factor that allows each country to have different stocks of research and development. RAD^d represents the log of domestic R&D capital stock within a county's manufacturing industry, and RAD^f represents the weighted lagged log of foreign R&D capital stock. Coe and Helpman weighted RAD^f by the ratio of imports relative to gross domestic product since the amount of information that is transmitted between countries depends upon the amount of contacts between them. In this specification, in half of the equations RAD^f is weighted by the ratio of imports to gross domestic product and in the rest of the equations it is weighted by the ratio of exports to gross domestic product. This model is then used to determine the importance of intranational and international productive knowledge spillovers.

The Data

To accomplish this task a series of regressions are run to examine the effect of the relative location of research and development on the total factor productivity for the manufacturing sector in thirteen countries between 1973 and 1994. The countries are Australia, Canada, Denmark, Finland, France, Great Britain, Germany, Italy, Japan, Netherlands, Norway, Sweden, and the United States and are selected due to the availability of data. The data is collected from several OECD data sources namely: ANBERD (Analytical Business Enterprise Research and Development database), the International Sectorial Database, and the International Direct Investment Statistics.

3 Empirical Results for the Manufacturing Industries

The regressions use time series data for each country's manufacturing industry. In the tables, the country name represents the nation whose industries are being examined. Below the country name is the designation for which trading partner and which weight is being examined. The effects on total factor productivity for the manufacturing industries are provided.

The tables each provide interesting insights into the long-term relationship between total factor productivity, growth, research and development, and the importance of the international knowledge transfers. It is not only the existence of knowledge transfers that are important, but also their origin since access to this knowledge spillover may be limited. Each of the tables illustrates the importance of international knowledge transfers to most of the countries where at least on a few occasions it is international rather than intranational knowledge transfers that are significant.

Table 1 provides an overview of the importance of international contact. The table uses side by side comparisons, of the benefits of the import versus export weights to measure the impact of foreign contacts upon the domestic economy. Table 1 illustrates that as a channel of knowledge spillovers both imports and exports are effective in some cases. For example, growth in the Canadian economy occurs due to increases in research and development from domestic sources but also from international knowledge spillovers from the United States. In this table, the omitted columns are the results of non-performing regressions. The second set of Tables labeled 2, 3, and 4 provide more detail on all of the regressions that underlie Table 1. These tables sort the countries from Table 1 into Non-European countries (2), Geographically Large European Nations (3), and Smaller European countries (4).

The omitted equations appear in Table 1 as blank columns. Of the remaining regressions shown in this table, most of these equations have more than one significant R&D coefficient. The equations that appear in Table 1 appear due to the stationary relationship between total factor productivity, domestic R&D, and foreign R&D.

Table 1: An Overview

Country	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS	AUS
Country-Foreign	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	D					B	D	D	D	D		D						D	D				
Sign on R&D^{d}	+	+					+	+	+	+	+		+						+	+				
Sign on R&D^{f}							+																	
Country	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN	CAN
Country-Foreign	AUS	AUS	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	B	D	B		B	F		F	F	B	D			D	B		B	D	D	D		B	B
Sign on R&D^{d}	+	+	+	+		+					+	+			+	+		+	+	+	+		+	+
Sign on R&D^{f}		+		+		+	-		-	-	+					+		+					+	+
Country	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN	DEN
Country-Foreign	AUS	AUS	CAN	CAN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	F	D	D	D	F		D	B	B	B	B			D	B	F	F	D	D	D	D	B	F
Sign on R&D^{d}	-		+	+	+			+	+	+	+	+			+	+			+	+	+	+	+	
Sign on R&D^{f}		+				-			+	+	-	-				-	-	+					-	-
Country	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN	FIN
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D			D	B										D			B			D				
Sign on R&D^{d}			+	+										+			+			+				
Sign on R&D^{f}			-	-													+							
Country	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA	FRA
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D			D	D		D		B			B	D				B		B			D	B	D	D
Sign on R&D^{d}			+	+		+		+			+	+				+		+			+	+	+	+
Sign on R&D^{f}								+			+					+		+				+		
Country	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR	GBR
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D					B	B		D	F	F	D	B	F	F		D							B	B
Sign on R&D^{d}					+	+		+			+	+				+							+	+
Sign on R&D^{f}					+	+			-	-		+	-	-		+							+	+
Country	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER	GER
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	D	D	B	D	D	D	B	D	D	D	B	B	D	D	B	D	B	D	D	D	D	D	D
Sign on R&D^{d}	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sign on R&D^{f}				+				+				-	-			+		+						
Country	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA	ITA
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	D	D	D	D	D	D	D	D	D	D	D	B	D	D	B	D	D	B	D	D	B	D	D
Sign on R&D^{d}	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sign on R&D^{f}													+			+			+			+		
Country	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN	JPN
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	NLD	NLD	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	D	D	B	B	B	D	D	D	D	D	D	D	B	D	B	B	B	B	B	D	D	B	B
Sign on R&D^{d}	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sign on R&D^{f}				-	-	-								-		-	-	-	+	+			-	-
Country	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD	NLD
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NOR	NOR	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	D	D	D	D	D	D	D	D	D	D	D	D	B	B	D	D	D	D	D	D	D	D	D
Sign on R&D^{d}	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
Sign on R&D^{f}														+	-									
Country	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR	NOR
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	SWI	SWI	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	B			D	B			D	B			F					D				B	F		
Sign on R&D^{d}	+			+	+			+	-								+				+			
Sign on R&D^{f}	+				+				+			+									+	-		
Country	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI	SWI
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	USA	USA
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D			D	D	B														B		B	B		
Sign on R&D^{d}			+	+	+														+		+	+		
Sign on R&D^{f}					+														+		-	-		
Country	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA	USA
Country-Foreign	AUS	AUS	CAN	CAN	DEN	DEN	FIN	FIN	FRA	FRA	GBR	GBR	GER	GER	ITA	ITA	JPN	JPN	NLD	NLD	NOR	NOR	SWI	SWI
Weight	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X	M	X
Significant R&D	D	B	B	D	D	B		B	F	B	F	F	B	B			B	B	D	B	D	D	D	D
Sign on R&D^{d}	+	+	+	+	+	+		+		+			+	+			+	+	+	+	+	+	+	+
Sign on R&D^{f}		+	-			+		+	-	-	-	-	+	+			-	+		+				

Key: M: Imports, X: Exports, D: Domestic, B: Both, F: Foreign, N: Neither, AUS: Austria, CAN: Canada, DEN: Denmark, FIN: Finland, FRA: France, GBR: Great Britain, GER: Germany, ITA: Italy, JPN: Japan, NLD: Netherlands, NOR: Norway, SWI: Switzerland, and USA: United States.

The question being investigated in this paper is not the existence of these relationships but rather how well the two different channels for knowledge transfer work. Coe and Helpman (1995) are among the first to empirically examine this idea. Coe and Helpman use a similar model with country level data across several OECD countries. They find that RAD^f and RAD^d both have positive coefficients. Coe and Helpman estimate that the elasticity coefficient of RAD^f is 0.294 and the elasticity coefficient of RAD^d is 0.0078. While both of these elasticities are positive, incomplete information, in particular the lack of standard errors or t-statistics, means the significance levels of the coefficients can not be determined. Table 1 shows that the positive relationship between foreign and domestic R&D displayed by Coe and Helpman in their work is not always replicated. In 172 of the 210 equations, the significant variables are all positive. This corresponds with Coe and Helpman's results and corresponds with the underlying economic theory. Increases in research and development regardless of where it occurs increase total factor productivity in the countries that are able to receive them.

The other 38 equations fail to follow the results generated by Coe and Helpman. In each of these regressions, a variable possesses a significant negative coefficient; although none of these equations possesses two significant and negative variables. This divergence may explain more about whether international knowledge spillovers are a good substitute for domestic research or a compliment for it than a flaw in the underlying theory. The equation examining the effect of increases in Australian research and development upon Danish productivity is the only regression in which RAD^d is both the only significant R&D variable and negative which means it failed to pass a one-tailed test on the relative contribution of R&D.

In 24 of these 38 regressions, both measures of research and development are significant, but one coefficient is negative while the other is positive. Each of these regressions illustrates that an increase in one source of research and development increases domestic productivity while increases in the other reduce it. For most of these 24 equations, RAD^d is positive while RAD^f possess a negative sign. When investigating total factor productivity for Japan, 15 equations produce significant variables that replicate the results by Coe and Helpman. In nine equations, RAD^d is positive and significant while RAD^f is negative and significant. Of these 9 equations, both regressions for Denmark, the Netherlands, and the United States appear as well as export weighted RAD^f for Canada, Germany, and Italy. These results are not restricted to Japan, they are replicated in several other countries including Denmark and the United States. There are also 13 equations where only RAD^f is significant as well as negative. Four of these equations occur when investigating total factor productivity in Great Britain where RAD^f from France and Italy are negative and significant. Another example of a significant negative variable occurs when examining the impact of increases in Canadian research and development upon the growth of total factor productivity in U. S. manufacturing industries. In this regression, increases in Canadian and domestic research and development significantly effect productivity. An unexpected result occurs as increases in Canadian R&D decrease U. S. productivity growth. This is contrary to the results uncovered by Coe and

Helpman and the underlying economic theory. It is not the only example of this however, as the 37 other equations also produce similar results.

A potential explanation for these results does exist. In some cases, increases in foreign research and development may not require additional research and development to adapt the knowledge spillovers to business within the country. The foreign research and development provides information that is a good substitute for domestic research and development. Foreign increases in research and development increase market share of imported goods and decreasing market share of domestically produced goods that have yet to deal with this innovation. In this case, countries are competing for the same pool of customers and the delay in innovation is initially costly to domestic producers but ultimately increases productivity and national output. An increase in Canadian research and development then has a negative impact upon productivity gains in the United States. The competition for American customers forces American firms to acquire the innovation, through international knowledge spillovers, so they can compete effectively with all their competitors.

In Table 1, research and development from the United States has a significant impact on total factor productivity in Canada, Denmark, Great Britain, and Japan. It does not significantly influence the other countries in the table, or at least this influence is not immediately apparent. Other countries including Germany, Great Britain, and Japan do provide significant knowledge spillovers to several trading partners. Germany provides significant knowledge spillovers to Canada, Denmark, Great Britain, Italy, Japan, the Netherlands, and the United States. Great Britain sends significant amounts of productive knowledge to Canada, Denmark, France Germany, Norway, and the United States. Japan generates research and development that is significant to Canada, Denmark, France, Germany, Italy, and the United States. In fact, all three of these countries are an important source of innovation for American manufacturing industries. All the countries in this series of tables send and receive knowledge spillovers.

Differences in a country's dependence on foreign research and development may be due to the relative openness of the industry and the economy. Relatively more trade and a relatively larger proportion of GDP that is the result of trade could lead to relatively more foreign contacts. The United States and other several other economies, can still be considered relatively closed economies and thus have fewer foreign contacts than their relatively more open counterparts which in turn may explain the disparity between these results. There may also be another reason for these differences. Unlike previous papers including the one by Coe and Helpman, this model does not control for indirect effects. This means that information flows originating from the United States and influencing production in Germany or France, which flow through an intermediary country, appear as if they originated in that intermediary instead of from the United States. This may also be the reason for the existence of the discrepancies between the results in Table 1 and those from Coe and Helpman.

Further examination of the significant research and development coefficients reveals no obvious single origin for the knowledge spillovers that flow through Table 1. In tables 2, 3, and 4, many of the countries provide international knowledge spillovers to their trading partners. This data also show that none of the countries, including the United States is the single dominant force in transmitting knowledge spillovers. This is contrary to the results produced by Park (1995), which show that most of the knowledge spillovers originated in the United States, while other countries are largely receivers of them.

Another result by Park that is contradicted here is the importance of international knowledge spillovers to the United States. He illustrates with country level data that international knowledge spillovers are much more important to the rest of the world than they are to the United States. His results are not reproduced here. Depending upon which channel is being examined, several countries including Germany and Japan provide significant knowledge spillovers to the United States. In many instances in Table 1, the external pool of knowledge and thus knowledge spillovers is more important than the internal R&D in explaining the country's ability to innovate. This is also true for the United States. Acs and Audretsch (1988) develop definitions of large and small firms to define the importance of external research and development. This paper uses an extension of this concept with international spillovers and uses a slightly different terminology. Extending Acs and Audretsch's work, the equivalent of a large firm in terms of a country can be identified as an inwardly focused country. It is like a large firm and independent of foreign knowledge spillovers whereas the equivalent of a small firm could be described as dual focused economy since it is significantly affected by international knowledge spillovers. By this definition, the results provided by Park show that only the United States could be considered an inwardly focused country and all the other countries are dual focused as they are much more responsive to international knowledge spillovers. However, Table 1 refutes this by showing that all countries, including the United States, are dependent upon international knowledge spillovers and so all the countries could be considered dual focused countries.

Since productivity in a dual focused country is sensitive to international knowledge transfers, the continued transmission of productive information is important. For many of the countries in Table 1 the importance of international knowledge spillovers depends upon which of the two channels is being examined. Often one of the equations shows the significant impact of foreign knowledge transfers upon the domestic economy's total factor productivity while the other shows international information flows to be insignificant. This means one channel may transmit the knowledge spillovers more effectively than the other. One of the details that needs to be clarified is the difference between imports and exports as channels of knowledge transfers.

The two different channels for dispersing productive information do not always have the same impact upon a recipient. In Table 2, the significant knowledge spillover coefficients produced by the two channels show no clear pattern. These results show that the significant coefficient in 6 regressions is RAD^f, in 38 others it's RAD^d, and in the last 27 both RAD^f and RAD^d are significant. Of the equations that use imports as the primary means of transmitting information between countries, one set of significant coefficients includes 24 regressions for RAD^d, 4 with RAD^f, and 8 where both measures of R&D are significant. The group of regressions using exports as the primary mechanism for knowledge spillovers includes 14 regressions where RAD^d is significant, 2 where RAD^f is significant, and 19 where both

Table 2: Countries Outside Europe: Japan, United States, Canada, and Australia

Country	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan
Foreign Country	Australia	Australia	Canada	Canada	Denmark	Denmark	Finland	Finland	France	France	Great Britain	Great Britain
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-5.724*	-5.140*	-6.085*	-6.041*	-5.267*	-5.022*	-5.128*	-5.549*	-6.070*	-5.961*	-5.570*	-5.585*
	(0.4095)	(0.6321)	(0.5472)	(0.3158)	(0.4104)	(0.4812)	(0.7960)	(0.5993)	(0.6400)	(0.6648)	(0.6551)	(0.6984)
RAD^d	0.191*	0.171*	0.203*	0.200*	0.176*	0.168*	0.171*	0.185*	0.203*	0.199*	0.186*	0.187*
	(0.0140)	(0.0215)	(0.0182)	(0.0107)	(0.0140)	(0.0164)	(0.0268)	(0.0203)	(0.215)	(0.0224)	(0.0220)	(0.0234)
RAD^f	-0.045	-0.354	0.876	-3.993***	-6.701***	-8.518***	-3.552	-1.226	32.406	19.087	-0.177	-0.164
	(0.2409)	(0.3061)	(2.0960)	(2.2231)	(3.6406)	(4.2721)	(4.0306)	(2.7955)	(58.4651)	(56.6120)	(0.5054)	(0.5509)
R^2	0.9394	0.9435	0.9457	0.9538	0.9489	0.9503	0.9418	0.9399	0.9403	0.9397	0.9397	0.9396
Adj R^2	0.9327	0.9372	0.9394	0.9485	0.9432	0.9447	0.9353	0.9332	0.9337	0.9330	0.9330	0.9329
Observations	21	21	21	20	21	21	21	21	21	21	21	21

Country	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan	Japan
Foreign Country	Germany	Germany	Italy	Italy	Netherlands	Netherlands	Norway	Norway	Switzerland	Switzerland	United States	United States
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-5.878*	-5.407*	-4.571*	-4.760*	-5.487*	5.406*	-5.860*	-5.870*	-5.809*	-6.033*	-5.113*	-5.037*
	(0.4200)	(0.3726)	(0.9888)	(1.2539)	(06694)	(0.9730)	(0.2587)	(0.2657)	(0.3880)	(0.4305)	(0.4253)	(0.4440)
RAD^d	0.196*	0.181*	0.152*	0.159*	0.183*	0.181*	0.195*	0.195*	0.194*	0.201*	0.171*	0.168*
	(0.0142)	(0.0127)	(0.0333)	(0.0422)	(0.0225)	(0.0326)	(0.0089)	(0.0091)	(0.0133)	(0.0142)	(0.0144)	(0.0151)
RAD^f	6.611	-21.526***	-2.754	-1.828	-2.855	-3.451	6.647*	5.973*	1.098	32.293	-12.166**	-12.023**
	(15.235)	(12.3409)	(2.1538)	(2.1966)	(5.9173)	(8.7247)	(1.8787)	(1.7981)	(5.1281)	(34.0584)	(5.6344)	(5.4342)
R^2	0.9399	0.9481	0.9443	0.9415	0.9400	0.9398	0.9642	0.9624	0.9394	0.9422	0.9518	0.9523
Adj R^2	0.9332	0.9423	0.9381	0.9350	0.9334	0.9331	0.9602	0.9582	0.9327	0.9357	0.9464	0.9470
Observations	21	21	21	21	21	21	21	21	21	21	21	21

Country	United States	United States	United States	United States	United States	United States	United States	United States	United States	United States	United States	
Foreign Country	Australia	Australia	Canada	Canada	Denmark	Denmark	Finland	France	France	Great Britain	Great Britain	
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Exports	Imports	Exports	Imports	Exports	
Intercept	-4.062*	-7.352*	-2.409*	-3.406*	-4.307*	-6.251999*	-7.111*	-0.844	-1.906***	-0.346	-0.405	
	(0.7091)	(0.8870)	(0.7483)	(0.5922)	(0.7960)	(0.72219821)	(0.7406)	(0.7355)	(1.0485)	(0.4822)	(0.6222)	
RAD^d	0.160*	0.291*	0.097*	0.136*	0.170*	0.247064*	0.281141*	0.034	0.075***	0.014	0.017	
	(0.0285)	(0.0355)	(0.0294)	(0.0236)	(0.0320)	(0.02887049)	(0.0296)	(0.0291)	(0.0416)	(0.0191)	(0.02458)	
RAD^f	0.467	1.914*	-5.970**	-4.322	8.816	26.862*	17.737535*	-283.428*	-155.96**	-2.875*	-2.848*	
	(0.3877)	(0.4018)	(2.7652)	(4.0050)	(6.5673)	(5.9753)	(3.2350)	(64.10628)	(84.7592)	(0.3571)	(0.4732)	
R^2	0.6907	0.8562	0.7365	0.6858	0.6964	0.8466	0.8787	0.8438	0.7200	0.9303	0.8982	
Adj R^2	0.6543	0.8393	0.7055	0.6488	0.6607	0.8286	0.8645	0.8255	0.6871	0.9220	0.8802	
Observations	20	20	20	20	20	20	20	20	20	20	20	

Country	United States	United States	United States	United States	United States	United States	United States	United States	United States	United States	Canada	Canada
Foreign Country	Germany	Germany	Japan	Japan	Netherlands	Netherlands	Norway	Norway	Switzerland	Switzerland	United States	United States
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-5.038*	-4.757*	-3.651*	-4.880*	-5.198*	-10.528*	-3.605*	-3.6083*	-3.817*	-3.569*	-1.930*	-1.884*
	(0.6107)	(0.6159)	(0.5376)	(0.5830)	(1.2058)	(1.6211)	(0.5707)	(0.5600)	(0.6787)	(0.8146)	(0.5117)	(0.5591)
RAD^d	0.198*	0.187*	0.145*	0.191*	0.205*	0.414*	0.143*	0.144*	0.150*	0.140*	0.087*	0.085*
	(0.0244)	(0.0246)	(0.0219)	(0.0232)	(0.0478)	(0.0639)	(0.0232)	(0.0228)	(0.0273)	(0.0316)	(0.0234)	(0.0257)
RAD^f	73.568*	58.176*	-0.583***	0.848*	15.416	61.074*	-5.109	-5.638	6.333	1.490	24.392**	20.724***
	(20.5325)	(18.8804)	(0.2912)	(0.2374)	(10.0337)	(13.7503)	(4.0671)	(3.7334)	(8.3395)	(60.9275)	(10.4312)	(10.5467)
R^2	0.8087	0.7846	0.7283	0.8082	0.7052	0.8446	0.6928	0.7040	0.6753	0.6643	0.4436	0.4027
Adj R^2	0.7862	0.7592	0.6963	0.7856	0.6705	0.8263	0.6566	0.6691	0.6371	0.6248	0.3818	0.3363
Observations	20	20	20	20	20	20	20	20	20	20	21	21

Country	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada	Canada
Foreign Country	Australia	Australia	Denmark	Denmark	Finland	France	Great Britain	Great Britain	Germany	Germany	Japan	Japan
Direction	Imports	Exports	Imports	Exports	Exports	Imports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-1.147**	-2.853*	-1.298**	-2.073*	-2.919*	0.537	0.781***	0.811	-1.836*	-1.338*	-1.005**	-1.770*
	(0.4590)	(0.7133)	(0.5149)	(0.5935)	(0.6109)	(0.5219)	(0.4316)	(0.4879)	(0.4230)	(0.4556)	(0.3639)	(0.3787)
RAD^d	0.052**	0.130*	0.051**	0.094*	0.1353*	-0.023	-0.034	-0.035	0.083*	0.060*	0.047**	0.079*
	(0.0214)	(0.0329)	(0.0239)	(0.0273)	(0.0281)	(0.0237)	(0.0196)	(0.0221)	(0.0194)	(0.0209)	(0.0172)	(0.0174)
RAD^f	-0.213	1.5286**	2.393	17.578**	15.527*	-259.630*	-2.561*	-2.602*	67.582**	27.280	-0.312	0.828*
	(0.4183)	(0.5331)	(7.0670)	(8.1284)	(4.3914)	(73.2892)	(0.5120)	(0.5913)	(23.6064)	(23.2473)	(0.3254)	(0.2561)
R^2	0.2849	0.5021	0.2792	0.4242	0.5719	0.5726	0.6965	0.6506	0.5015	0.3261	0.3098	0.5410
Adj R^2	0.2055	0.4467	0.1991	0.3602	0.5243	0.5251	0.6628	0.6117	0.4462	0.2513	0.2331	0.4899
Observations	21	21	21	21	21	21	21	21	21	21	21	21

Country	Canada	Canada	Canada	Canada	Australia	Australia	Australia	Australia	Australia	Australia	Australia	Australia
Foreign Country	Netherlands	Norway	Norway	Switzerland	Canada	Canada	France	France	Germany	Italy	Norway	Norway
Direction	Exports	Imports	Exports	Imports	Imports	Exports	Imports	Exports	Imports	Imports	Imports	Exports
Intercept	-3.710**	-0.983**	-0.974**	-1.099**	-2.218*	-2.211*	-3.250	-2.668*	-2.525*	-2.061*	-2.453*	-2.450*
	(1.3657)	(0.3621)	(0.3578)	(0.4359)	(0.3242)	(0.1899)	(0.3813)	(0.3876)	(0.2183)	(0.3747)	(0.1916)	(0.1928)
RAD^d	0.167**	0.046**	0.046**	0.050**	0.107*	0.109*	0.156*	0.129*	0.122*	0.101*	0.119*	0.119*
	(0.0616)	(0.0170)	(0.0168)	(0.0203)	(0.0151)	(0.0090)	(0.0181)	(0.0185)	(0.0106)	(0.0180)	(0.0094)	(0.0095)
RAD^f	38.266***	-4.472	-4.898	3.524	-0.783	-3.227	145.438**	37.675	9.111	-1.771	-0.021	-0.177
	(18.7555)	(4.0970)	(3.7730)	(8.9257)	(2.1465)	(2.3010)	(62.7445)	(59.6336)	(14.4627)	(1.4811)	(2.5423)	(2.3791)
R^2	0.4108	0.3196	0.3367	0.2808	0.8968	0.9068	0.9225	0.9016	0.9016	0.9068	0.8994	0.8994
Adj R^2	0.3454	0.2440	0.2630	0.2009	0.8847	0.8958	0.9139	0.8906	0.8906	0.8964	0.8882	0.8882
Observations	21	21	21	21	20	21	21	21	21	21	21	21

Note: Significant at: * a 1% level of significance, ** a 5 % level of significance, and *** a 10% level of significance.

coefficients are significant. Using exports as the channel means that, more often, both variables will be significant.

In Table 3 and 4, the elasticity coefficient results from Table 2 are replicated. Once again it appears that using exports instead of imports as the mechanism for the flows of information across countries means that more often both foreign and domestic sources of innovation will provide significant contributions to economic growth. For many of the countries including Japan, changing from imports to exports makes the country appear even more dependent on international knowledge flows. Japan, Canada, and the United States all conform to this explanation. Using imports to explain knowledge spillovers, in Japan the significant variables are only domestic research and development in 9 of the 12 equations. In the other 3 regressions, both domestic and foreign sources of innovation are significant sources of productive growth. Shifting to exports as the source of knowledge spillovers, in Japan 7 of the 12 regressions reveal that only domestic research and development is a significant source of innovation. Now however, the other 5 equations present evidence that both foreign and domestic knowledge acquisitions are significant. This explanation is true for non-European countries as well as for countries in Europe.

To further examine the channel of knowledge transfers, one must examine the impact of using imports versus exports as a channel to transmit knowledge transfers. There are 91 pairs of regressions; one equation uses the fraction of imports to GNP as a weight while the other uses the corresponding fraction with exports replacing imports in the weight. Forty-six equations exist where both the import and export regressions appear in the table, and the signs and significant variables in these pairs are identical. There is no difference in the significance of each variable or in the signs for the R&D coefficients. Most of these pairs of equations possess significant variables that are positive. Some of these pairs show only one of the measures of research and development to be positive and significant, while the insignificant variable may or may not have a positive coefficient. In others of these identical pairs both sets of variables are significant and the sign on each of the research and development variables is positve. These results are consistent with the theory, but some exceptions do exist. Two notable exceptions occur when examining the importance for total factor productivity in Switzerland of RAD^f from Norway and in the United States of RAD^f from Great Britain. Both sets of regressions have foreign research and development as a significant variable, however the sign of these coefficients is negative for each equation in both of the pairs. The importance of British knowledge spillovers for the United States is different from the importance of Norwegian knowledge flows to Switzerland as the latter regression also produces a significant RAD^d with the correct sign. In the former equation, RAD^d has the correct sign but remains insignificant. The equations, regardless of which channel of information spillovers is examined, appear to contradict the theory, when in fact these signs simply expose the relationship between domestic and foreign research and development. In these regressions foreign R&D is a very good substitute for

Table 3: Large European Countries: France, Germany, Great Britain, and Italy

Country	France	France	France	France	France	France	France	France	France	France	France	France
Foreign Country	Canada	Canada	Denmark	Finland	Germany	Germany	Japan	Netherlands	Switzerland	Switzerland	United States	United States
Direction	Import	Export	Export	Export	Import	Export	Export	Export	Import	Export	Import	Export
Intercept	-2.851*	-3.130*	-3.332*	-3.731*	3.569*	-3.204*	-3.506*	-4.713*	-3.188*	-3.595*	-3.229*	-3.273*
	(0.3170)	(0.2053)	(0.3402)	(0.3549)	(0.2202)	(0.2561)	(0.2103)	(0.5196)	(0.2441)	(0.2398)	(0.3056)	(0.3201)
RAD^d	0.113*	0.123*	0.132*	0.148*	0.141*	0.127*	0.138*	0.186*	0.126*	0.141*	0.128*	0.130*
	(0.0124)	-0.0082	(0.01369263)	(0.0143)	(0.0088)	(0.0103)	(0.0085)	(0.0206)	(0.0100)	(0.0093)	(0.0123)	(0.0129)
RAD^f	-1.389	1.828	2.054068	3.912***	29.214**	1.756	0.330**	18.545*	0.294	62.313**	1.144	1.918
	(1.54066)	(1.8365)	(3.86834729)	(2.1193)	(10.2258)	(10.8547)	(0.1184)	(5.9455)	(4.1391)	(24.0645)	(5.1796)	(5.0148)
R^2	0.9292	0.9299	0.9244	0.9355	0.9472	0.9234	0.9463	0.9502	0.9233	0.9441	0.9235	0.9239
Adj R^2	0.9208	0.9216	0.9160	0.9283	0.9413	0.9148	0.9403	0.9446	0.9147	0.9379	0.9149	0.9154
Observations	20	21	21	21	21	21	21	21	21	21	21	21
Country	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain	Great Britain
Foreign Country	Denmark	Denmark	Finland	France	France	Germany	Germany	Italy	Italy	Japan	United States	United States
Direction	Import	Export	Export	Import	Export	Import	Export	Import	Export	Export	Import	Export
Intercept	-4.747*	-6.189*	-5.645*	-0.629	-1.125	-3.614*	-4.808*	0.970	2.604	-3.857*	-5.617*	-5.374*
	(1.17238)	(1.4670)	(1.6508)	(0.3773)	(0.9630)	(1.0792)	(1.0400)	(1.8373)	(1.6737)	(0.9865)	(1.1761)	(1.3490)
RAD^d	0.207*	0.272*	0.247*	0.027	0.047	0.156*	0.209*	-0.047	-0.119	0.166*	0.245*	0.235*
	(0.0531)	(0.0661)	(0.0742)	(0.0168)	(0.0430)	(0.0486)	(0.0467)	(0.0817)	(0.0743)	(0.0444)	(0.0527)	(0.0607)
RAD^f	20.416***	34.349**	14.997	-412.967*	-264.607**	30.665	81.116**	-11.395**	-12.902*	0.569	44.295**	36.237***
	(11.4141)	(14.4319)	(8.6694)	(43.1286)	(100.1393)	(42.3935)	(37.1009)	(4.8632)	(3.6000)	(0.4709)	(17.1532)	(18.2271)
R^2	0.5912	0.6425	0.5862	0.9335	0.6649	0.5159	0.6256	0.6393	0.7381	0.5453	0.6598	0.6084
Adj R^2	0.5328	0.5914	0.5271	0.9240	0.6170	0.4467	0.5721	0.5877	0.7007	0.4803	0.6112	0.5524
Observations	17	17	17	17	17	17	17	17	17	17	17	17
Country	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany
Foreign Country	Australia	Australia	Canada	Canada	Denmark	Denmark	Finland	Finland	France	France	Great Britain	Great Britain
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-3.278*	-3.734*	-3.014*	-3.335*	-2.953*	-3.557*	-3.534*	-4.267*	-3.077*	-3.627*	-2.548*	-2.374*
	(0.3756)	(0.6328)	(0.4987)	(0.3020)	(0.4066)	(0.5128)	(0.7578)	(0.5004)	(0.5350)	(0.5701)	(0.5292)	(0.5369)
RAD^d	0.133*	0.152*	0.122*	0.133*	0.120*	0.144*	0.143*	0.173*	0.125*	0.147*	0.104*	0.097*
	(0.0155)	(0.0260)	(0.0201)	(0.0124)	(0.0168)	(0.0211)	(0.0308)	(0.0205)	(0.0218)	(0.0233)	(0.0215)	(0.0218)
RAD^f	0.010	0.231	-0.855	3.446***	-3.646	2.856	1.330	4.972**	-19.053	32.552	-0.595	-0.744***
	(0.1996)	(0.2769)	(1.7275)	(1.9160)	(3.2580)	(4.1135)	(3.4716)	(2.1098)	(44.2563)	(43.9345)	(0.3697)	(0.3835)
R^2	0.8593	0.8645	0.8502	0.8724	0.8638	0.8629	0.8604	0.8925	0.8607	0.8634	0.8770	0.8836
Adj R^2	0.8437	0.8495	0.8326	0.8574	0.8538	0.8477	0.8449	0.8805	0.8452	0.8483	0.8633	0.8707
Observations	21	21	20	20	21	21	21	21	21	21	21	21
Country	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany	Germany
Foreign Country	Italy	Italy	Japan	Japan	Netherlands	Netherlands	Norway	Norway	Switzerland	Switzerland	United States	United States
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-1.532***	-2.305**	-3.259*	-3.713*	-3.131*	-4.809*	-3.264*	-3.260*	-3.101*	-3.150*	-3.467*	-3.545*
	(0.8139)	(1.0408)	(0.2917)	(0.3089)	(0.6256)	(0.8265)	(0.3026)	(0.3021)	(0.3451)	(0.3807)	(0.4582)	(0.4797)
RAD^d	0.062***	0.093**	0.133*	0.150*	0.127*	0.1950*	0.133*	0.133*	0.126*	0.128*	0.141*	0.144*
	(0.0332)	(0.0424)	(0.0121)	(0.0127)	(0.0255)	(0.0336)	(0.0126)	(0.0126)	(0.0143)	(0.0153)	(0.0188)	(0.0197)
RAD^f	-3.623**	-1.592	-0.186	0.322**	-1.250	13.269***	-0.750	-0.885	-3.882	-13.886	3.172	3.931
	(1.6040)	(1.6499)	(0.1511)	(0.1228)	(5.0025)	(6.7075)	(1.9893)	(1.8511)	(4.1208)	(27.3704)	(5.4836)	(5.3032)
R^2	0.8904	0.8662	0.8702	0.8983	0.8598	0.8844	0.8604	0.8610	0.8659	0.8613	0.8618	0.8634
Adj R^2	0.8782	0.8513	0.8558	0.8870	0.8442	0.8716	0.8449	0.8456	0.8510	0.8458	0.8465	0.8483
Error Correction	-4.074*	-3.383*	-3.243*	-3.434*	-2.611**	-3.273*	-3.024*	-3.108*	-3.563*	-2.549**	-3.613*	-4.062*
Observations	21	21	21	21	21	21	21	21	21	21	21	21
Country	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy
Foreign Country	Australia	Australia	Canada	Canada	Denmark	Denmark	Finland	Finland	France	France	Great Britain	Great Britain
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-4.666*	-4.651*	-4.478*	-4.550*	-4.361*	-4.355*	-4.141*	-4.922*	-4.709*	-4.790*	-4.203*	-4.250*
	(0.2852)	(0.5033)	(0.3453)	(0.2551)	(0.3164)	(0.3950)	(0.5219)	(0.4419)	(0.4228)	(0.4384)	(0.4113)	(0.4334)
RAD^d	0.157*	0.156*	0.151*	0.154*	0.146*	0.146*	0.139*	0.165*	0.158*	0.161*	0.141*	0.143*
	(0.0099)	(0.0173)	(0.0113)	(0.0083)	(0.0110)	(0.0136)	(0.0176)	(0.0152)	(0.0143)	(0.0148)	(0.0138)	(0.0145)
RAD^f	0.146	0.067	-0.952	-1.769	-4.078	-3.610	-3.956	2.939	24.563	35.336371	-0.566	-0.504
	(0.2542)	(0.3756)	(2.5754)	(8.1976)	(4.2513)	(5.3335)	(4.3164)	(3.16925)	(63.0410)	(60.0993)	(0.5267)	(0.5760)
R^2	0.9589	0.9581	0.9584	0.9581	0.9604	0.9593	0.9602	0.9603	0.9584	0.9590	0.9610	0.9601
Adj R^2	0.9534	0.9525	0.9528	0.9526	0.9552	0.9538	0.9549	0.9550	0.9528	0.9535	0.9558	0.9547
Observations	18	18	18	18	18	18	18	18	18	18	18	18
Country	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy	Italy
Foreign Country	Germany	Germany	Japan	Japan	Netherlands	Netherlands	Norway	Norway	Switzerland	Switzerland	United States	United States
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-4.975*	-4.431*	-4.564*	-4.892*	-4.816*	-5.502*	-4.457*	-4.474*	-4.676*	-4.964*	-4.315*	-4.284*
	(0.2853)	(0.3000)	(0.2378)	(0.2766)	(0.4745)	(0.7252)	(0.2169)	(0.2253)	(0.270)	(0.3038)	(0.3425)	(0.3634)
RAD^d	0.167*	0.149*	0.153*	0.164*	0.162*	0.185*	0.148*	0.149*	0.157*	0.165*	0.145*	0.144*
	(0.0098)	(0.0103)	(0.0085)	(0.0095)	(0.0161)	(0.0244)	(0.0079)	(0.0082)	(0.0094)	(0.0099)	(0.0117)	(0.0125)
RAD^f	31.882***	-10.845	0.044	0.329***	3.860	13.811	5.876***	4.740	4.019	65.078***	-6.886	-6.829
	(15.4474)	(14.8235)	(0.2244)	(0.1816)	(6.5195)	(10.2505)	(2.9571)	(2.9376)	(5.3896)	(35.9505)	(6.8608)	(6.7391)
R^2	0.9673	0.9595	0.9581	0.9656	0.9590	0.9625	0.9668	0.9642	0.9595	0.9655	0.9607	0.9607
Adj R^2	0.9629	0.9541	0.9525	0.9610	0.9535	0.9576	0.9623	0.9595	0.9541	0.9609	0.9554	0.9555
Observations	18	18	18	18	18	18	18	18	18	18	18	18

Note: Significant at: * a 1% level of significance, ** a 5 % level of significance, and *** a 10% level of significance.

Table 4: Small European Countries: Denmark, Finland, Norway, Netherlands, and Switzerland

Country	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	
Foreign Country	Australia	Australia	Canada	Canada	Finland	Finland	France	Great Britain	Great Britain	Germany	Germany	
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Exports	Imports	Exports	Imports	Exports	
Intercept	-1.177*	0.200	-1.949*	-1.428*	-2.160*	-0.167	-2.217*	-2.960*	-2.683*	-0.945**	-0.940**	
	(0.3559)	(0.3631)	(0.4448)	(0.3024)	(0.6926)	(0.3839)	(0.5467)	(0.4232)	(0.5378)	(0.3428)	(0.3218)	
RAD^d	-0.054*	-0.008	0.087*	0.069*	0.098*	0.009	0.101*	0.133*	0.121*	0.045**	0.044*	
	(0.0164)	(0.0166)	(0.01953)	(0.0147)	(0.0310)	(0.0175)	(0.0246)	(0.0189)	(0.0240)	(0.0156)	(0.0147)	
RAD^f	-0.374	-1.310*	3.976	-4.304	5.952	-10.181*	112.741	2.012*	1.670**	-39.304**	-38.069**	
	(0.2945)	(0.2500)	(2.6905)	(7.5946)	(5.1713)	(2.5456)	(67.8041)	(0.4843)	(0.6350)	(17.3366)	(14.8386)	
R^2	0.6143	0.8437	0.6263	0.5837	0.6078	0.7876	0.6379	0.7957	0.7035	0.6786	0.6991	
Adj R^2	0.5661	0.8242	0.5796	0.5317	0.5588	0.7611	0.5927	0.7701	0.6665	0.6384	0.6615	
Observations	19	19	19	19	19	19	19	19	19	19	19	
Country	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Denmark	Finland	Finland
Foreign Country	Japan	Japan	Netherlands	Netherlands	Norway	Norway	Switzerland	Switzerland	United States	United States	Canada	Canada
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-1.419*	-0.964*	-0.426	0.834	-1.426	-1.418*	-1.823*	-1.361*	-0.546	-0.543	-4.083*	-4.186*
	(0.2921)	(0.3213)	(0.5408)	(0.6669)	(0.3035)	(0.3005)	(0.3296)	(0.4232)	(0.3192)	(0.3633)	(0.4219)	(0.2341)
RAD^d	0.643*	0.046*	0.021	-0.035	0.065*	0.064*	0.055*	0.063*	0.027***	0.026	0.184*	0.193*
	(0.0137)	(0.0146)	(0.0243)	(0.0298)	(0.0143)	(0.0141)	(0.0152)	(0.0184)	(0.0145)	(0.0166)	(0.0185)	(0.0106)
RAD^f	0.300	-0.490**	-14.694**	-31.112*	1.911	2.513	-9.404	-12.175	-22.838*	-20.290*	-2.930	-8.801**
	(0.2461)	(0.1968)	(6.8177)	(8.5945)	(3.4928)	(3.2617)	(6.1190)	(46.8662)	(5.9337)	(6.2514)	(3.1083)	(3.1953)
R^2	0.6115	0.6940	0.6709	0.7665	0.5831	0.5905	0.6300	0.5771	0.7795	0.7439	0.9387	0.9554
Adj R^2	0.5629	0.6557	0.6298	0.7374	0.5310	0.5394	0.5837	0.5243	0.7519	0.7119	0.9315	0.9502
Observations	19	19	19	19	19	19	19	19	19	19	20	20
Country	Finland	Finland	Finland	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway	Norway
Foreign Country	Italy	Netherlands	Norway	Australia	Canada	Denmark	Finland	France	Great Britain	Japan	Switzerland	Switzerland
Direction	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Imports	Exports
Intercept	-6.512*	-5.879*	-4.626*	-1.913*	-1.084***	-2.381*	-1.573***	1.319**	0.676	-1.247**	-1.756*	0.098
	(1.3641)	(0.6481)	(0.3385)	(0.5386)	(0.5374)	(0.5360)	(0.8761)	(0.6078)	(0.8673)	(0.5060)	(0.5438)	(0.5241)
RAD^d	0.293*	0.264*	0.210*	0.084*	0.047***	0.105*	0.069***	-0.059**	-0.030	0.056**	0.077*	-0.002
	(0.0614)	(0.0292)	(0.0158)	(0.0244)	(0.0240)	(0.0242)	(0.0394)	(0.0271)	(0.0386)	(0.0232)	(0.0246)	(0.0231)
RAD^f	6.474	23.720**	-5.141	0.597**	-0.242	12.077*	2.076	-207.566*	-1.329**	-0.321	11.608**	-104.734*
	(4.6481)	(11.1464)	(4.5489)	(0.2286)	(8.6626)	(3.4366)	(3.0178)	(43.8620)	(0.5594)	(0.2246)	(5.1667)	(30.5549)
R^2	0.9112	0.9214	0.9081	0.4548	0.2067	0.5649	0.2310	0.6818	0.4235	0.3019	0.4064	0.5551
Adj R^2	0.9013	0.9127	0.8979	0.3821	0.1010	0.5069	0.1284	0.6393	0.3466	0.2088	0.3273	0.4958
Observations	21	21	21	18	18	18	18	18	18	18	18	18
Country	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands
Foreign Country	Australia	Australia	Canada	Canada	Denmark	Denmark	Finland	Finland	France	France	Great Britain	Great Britain
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-4.177*	-3.802*	-4.029*	-4.099*	-3.818*	-3.841*	-4.335*	-3.934*	-4.335*	-4.351*	-4.262*	-3.906*
	(0.2369)	(0.3713)	(0.2970)	(0.1955)	(0.2462)	(0.3012)	(0.4600)	(0.3382)	(0.3752)	(0.3733)	(0.3944)	(0.4071)
RAD^d	0.170*	0.155*	0.165*	0.167*	0.156*	0.157*	0.177*	0.160*	0.177*	0.177*	0.174*	0.159*
	(0.0099)	(0.0154)	(0.0119)	(0.0086)	(0.0103)	(0.0125)	(0.0188)	(0.0140)	(0.0153)	(0.0153)	(0.0161)	(0.0166)
RAD^f	0.101	-0.210	-0.489	1.056	-4.535	-3.638	1.733	-1.169	32.982	32.507	0.192	-0.229
	(0.1734)	(0.2263)	(1.5984)	(4.3086)	(2.7169)	(3.3370)	(3.0465)	(1.9859)	(44.6260)	(41.0482)	(0.4003)	(0.4266)
R^2	0.9629	0.9641	0.9624	0.9623	0.9678	0.9648	0.9629	0.9630	0.9634	0.9636	0.9627	0.9628
Adj R^2	0.9583	0.9596	0.9577	0.9576	0.9637	0.9604	0.9583	0.9583	0.9588	0.9590	0.9580	0.9582
Observations	19	19	19	19	19	19	19	19	19	19	19	19
Country	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands	Netherlands
Foreign Country	Germany	Germany	Italy	Italy	Japan	Japan	Norway	Norway	Switzerland	Switzerland	United States	United States
Direction	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Intercept	-4.090*	-3.846*	-3.100*	-3.006*	-4.108*	-4.061*	-4.102*	-4.101*	-4.181*	-3.953*	-3.866*	-3.852*
	(0.2505)	(0.2183)	(0.5800)	(0.7267)	(0.1909)	(0.2400)	(0.1968)	(0.1966)	(0.2253)	(0.2649)	(0.2678)	(0.2828)
RAD^d	0.167*	-0.157*	0.126*	0.123*	0.168*	0.166*	0.167*	0.167*	0.171*	0.162*	0.158*	0.157*
	(0.0104)	(0.0091)	(0.0238)	(0.0298)	(0.0081)	(0.0100)	(0.0084)	(0.0084)	(0.0094)	(0.0106)	(0.0111)	(0.0117)
RAD^f	-0.523	-17.328***	-2.953***	-2.561	-0.134	-0.034	-0.444	-0.3645	2.646	-20.612	-5.326	-5.003
	(11.2174)	(8.9158)	(1.6335)	(1.6511)	(0.1420)	(0.1302)	(1.9995)	(1.8843)	(3.6974)	(26.1038)	(4.4083)	(4.3083)
R^2	0.9622	0.9694	0.9686	0.9671	0.9641	0.9623	0.9623	0.9622	0.9633	0.9636	0.9653	0.9651
Adj R^2	0.9574	0.9656	0.9646	0.9630	0.9597	0.9576	0.9575	0.9575	0.9587	0.9590	0.9610	0.9607
Observations	19	19	19	19	19	19	19	19	19	19	19	19
Country	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland	Switzerland						
Foreign Country	Canada	Canada	Denmark	Netherlands	Norway	Norway						
Direction	Imports	Exports	Imports	Imports	Imports	Exports						
Intercept	-2.601*	-2.749*	-4.056*	-4.871*	-3.103*	-3.090*						
	(0.4349)	(0.2702)	(0.3425)	(0.5175)	(0.3011)	(0.3008)						
RAD^d	0.110*	0.118*	0.171*	0.204*	0.133*	0.132*						
	(0.0179)	(0.0113)	(0.0147)	(0.0217)	(0.0130)	(0.0130)						
RAD^f	-2.180	-4.794	18.056*	26.812*	-7.634**	-7.212**						
	(2.5660)	(2.9324)	(4.8057)	(7.1812)	(3.4700)	(3.2290)						
R^2	0.8629	0.8765	0.9013	0.9007	0.8612	0.8621						
Adj R^2	0.8468	0.8620	0.8903	0.8897	0.8458	0.8468						
Observations	20	20	21	21	21	21						

Note: Significance terms: * is a 1% level of significance, ** is a 5 % level of significance, and *** is a 10% level of significance.

additional domestic research and development, so an increase in foreign R&D decreases domestic R&D regardless of which channel is being observed.

However in 45 of these pairs of regressions, there is a discrepancy between the two regressions when the two different channels of knowledge spillovers are inspected. There could be a difference in a sign or the level of significance of one or both of the research and development coefficients. In 22 of the equations the difference is due to a change of significance for one of the variables. In one of the equations from each of these pairs only domestic R&D is significant while in the other equation both sources of R&D provide a significant contribution to improvements in a country's total factor productivity. Clearly, one of the channels is undervaluing the importance of foreign productive knowledge acquisition upon the domestic economy. This may be a consequence of the types of goods traded between these two countries as one of the channels fails to catch the relative importance of intraindustry trade versus interindustry trade between these two nations.

Some of the pairs of regressions also have another difference between the two equations. In 11 of the equations the difference is due to opposite signs on at least one of the research and development variables. Nine of these incidents occur in connection with the insignificant one, while the other 2 involve the significant one. Japanese research and development significantly affects total factor productivity in the United States through imports and its effect is positive whereas through exports it has a negative impact. The other instance involving a significant research and development variable is generated for Danish total factor productivity and RAD^f from the Netherlands. In both of the equations, RAD^d is insignificant and RAD^f is significant. The difference between these equations is using imports RAD^d is positive and RAD^f is negative while the signs of the coefficients reverse when exports are used as the channel for knowledge spillovers.

Differences in the use of the two channels for knowledge spillovers appear when categorizing countries as large and small. Here a large country is a member of the G-7 and a small one is not a G-7 member. Table 5 demonstrates that international knowledge spillovers are important to both groups of countries. Each grouping illustrates a range of the relative importance of international knowledge spillovers. It is interesting to note that large countries are more reliant on the export channel for knowledge spillovers than smaller nations, while the spillovers transmitted by imports display only slight differences between large and small countries. Looking at the results in terms of whether the country is in Europe or not also provides additional information. In general countries not in Europe tend to have more significant international spillovers than the countries of Europe especially when examining export transmitted spillovers. In Table 5, these international knowledge spillovers seem more important to Canada, Japan, and the United States than to their European counterparts. Additionally, Table 5 illustrates an aspect of the relationship between RAD^d and RAD^f that does not change with the channel of knowledge spillovers, regardless of the channel used, domestic and international knowledge spillovers are inputs for future economic growth.

Table 5: Significant channels of R&D by Country

Imports	Domestic	Percentage	Foreign	Percentage	Both	Percentage	Number of Equations
Australia	5	.83	0	0	1	.17	6
Canada	5	.56	2	.22	2	.22	9
Denmark	6	.60	1	.11	3	.30	10
Finland	1	.50	0	0	1	.50	2
France	3	.75	0	0	1	.25	4
Germany	11	.92	0	0	1	.08	12
Great Britain	1	.20	2	.40	2	.40	5
Italy	10	.83	0	0	2	.17	12
Japan	8	.67	0	0	4	.33	12
Netherlands	11	.92	0	0	1	.08	12
Norway	1	.20	0	0	4	.80	5
Switzerland	1	.25	0	0	3	.75	4
United States	5	.50	2	.20	3	.30	10
G-7	43	.67	6	.09	15	.23	64
Non-G-7	25	.64	1	.03	13	.33	39
European	45	.68	3	.05	10	.27	66
Non-European	23	.62	4	.11	10	.27	37
Exports	**Domestic**	**Percentage**	**Foreign**	**Percentage**	**Both**	**Percentage**	**Number of Equations**
Australia	4	1.00	0	0	0	0	4
Canada	2	.22	1	.11	6	.67	9
Denmark	4	.36	4	.36	3	.18	11
Finland	2	.67	0	0	1	.33	3
France	4	.50	0	0	4	.50	8
Germany	7	.58	0	0	5	.42	12
Great Britain	2	.29	2	.29	3	.43	7
Italy	10	.83	0	0	2	.17	12
Japan	5	.42	0	0	7	.58	12
Netherlands	11	.92	0	0	1	.08	12
Norway	2	.50	2	.50	0	0	4
Switzerland	1	.50	0	0	1	.50	2
United States	3	.27	1	.09	7	.64	11
G-7	33	.46	4	.06	34	.48	71
Non-G-7	24	.67	6	.17	6	.17	36
European	43	.61	8	.11	20	.28	71
Non-European	14	.39	2	.06	20	.55	36

This table looks at the significant sources of R&D for the equations presented in tables 1, 2,3, and 4. The top part of the table looks at imports and the bottom half looks exports as the channel for transmitting the spillovers. The term Domestic refers to equations with only the domestically produced R&D variable as being significant. The term Foreign refers to equations with only the foreign produced R&D variable as being significant. The term Both refers to equations where both sources of R&D are significant. Percentages are calculated separately for each row.

Advances in total factor productivity are determinants of economic growth. The information provided in this inspection, of the manufacturing sector's total factor productivity, illustrates some important points. Each economy's response to changes in domestic and international knowledge acquisition provides evidence for the importance of foreign research and development for each of the national economies studied here. Some nations provide more productive knowledge spillovers than others, while other economies are much more reliant on domestic knowledge spillovers. The importance of information flows from one nation to another in part depends on the relationship between the countries, the types of goods in which each nation tends to specialize, and the amount of contact between them.

Once these facts are taken into account, it is possible to see how interconnected the national economies truly are as well as the importance of these international contacts for continued growth of domestic manufacturing industries. However, national economies are changing. The service sector is becoming relatively more important in advanced economies and the information provided here does not directly address these service sectors.

4 Conclusions

This paper illustrates the importance of trade as a channel for knowledge spillovers. In particular it examines the implicit assumptions made by others that imports and exports are prefect substitutes as channels in transmitting knowledge spillovers. In some instances, they do provide similar results but in many others, the results are not identical. For example, in this paper international knowledge flows between France and Great Britain, using either measure, affect the total factor productivity in the other country. Other examples include American total factor productivity with knowledge spillovers from Great Britain, Canadian total factor productivity with informational flows from the United States and Great Britain, German total factor productivity with spillovers from the United States. Sometimes imports provide more significant foreign informational flows than exports, while at other time the reverse is true. A couple of the instances occur for the United States, with knowledge spillovers from Australia, Denmark, and France. Additional instances include total factor productivity in Canada, France, and Switzerland with knowledge spillovers from Germany. Clearly both channels are important but the significance and impacts are not always identical.

International trade provides participants with a network of international contacts through which knowledge transfers occur. International trade is based on comparative advantage and through international knowledge spillovers, it has the potential to alter the comparative advantage of a firm, industry, or nation. Research and development is often the basis of comparative advantage so profit maximization often necessitates export of the product to the rest of the world market to reduce research costs per unit to the lowest possible level. Through international trade a firm with a comparative advantage exports, and hence transmits knowledge spillovers to competitors and non-competitors alike, and which in turn dissipates its comparative advantage through contact with other firms. Importers acquire knowledge spillovers and possibly comparative advantage as well. This explanation corresponds with the Product Life Cycle Model stated by M. V. Posner and expanded by Raymond Vernon where comparative advantage in a particular good changes as the product becomes more standardized.[5]

Acquiring knowledge spillovers through exports is very different. Gaining knowledge spillovers through exports may strengthen comparative advantage, aid advancement of a domestic industry up the quality ladder, and improve the competitive position of an industry. Taiwan is an example of a country that initially exported low quality goods that took advantage of its comparative advantage in unskilled labor. However, foreign customers wanted more, which pushed the firms up the quality ladder as they acquired flows of productive information.

International knowledge spillovers may improve the performance of domestic industries and the nation as a whole, but it may also harm economic growth. As productive knowledge flows in and out of a country, neoclassical theory suggests comparative advantage and competitive position are either strengthened or weakened for the firm or industry. More imports and exports mean more trade. More trade means more access to gains from trade, access to international knowledge spillovers, and possibly more productive knowledge flowing to trading partners. Since receiving more spillovers means more growth, while transmitting more knowledge spillovers may reduce comparative advantage and growth, any policy initiative that alters trade alters transmission and reception of productive information flows and ultimately may alter the rate of growth in an economy.

ENDNOTES

1. Note one such article is H. Gersbach and A. Schmutzler, *Journal of Economics and Management Strategy*, Summer 2003, 12(2), pp. 179 - 205.
2. R. C. Levin, "Appropriability, R & D Spending, and Technological Performance", *American Economic Review*, May 1988, 78 (2), pp. 424 - 428.
3. For more information on the theory of Learning by Doing see Nancy Stokey (1988) and Alwyn Young (1991). For more information on acquiring knowledge through exports see Grossman and Helpman (2005) and Keller (2004).
4. Note for a more theoretical set up of the model see G. M. Grossman and E. Helpman, 1991, "Trade, knowledge spillovers, and growth*", European Economic Review*, 35 (5), 517-526.
5. A. Deardoff, "Testing Trade Theories and predicting Trade Flows" in R. Jones and P. Kenen (eds.), *Handbook of International Economics, Volume 1: International Trade*, New York: North-Holland, 1984, pp. 493-499.

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