The University of Nottingham

research paper series

Globalisation, Productivity and Technology

Research Paper 2007/07

Exports and international knowledge transfer: Evidence from UK firms

by

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The Centre acknowledges financial support from The Leverhulme Trust under Programme Grant F114/BF

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Acknowledgements

Financial support from the Leverhulme Trust (Programme Grant F114-BF) is gratefully acknowledged.

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Abstract
Within the recent literature studying participation in international markets using micro data, a small number have suggested that firms benefit from their exposure to international markets. One channel considered for this role has been investments in R&D. A common finding in this literature is that firms involved in international trade are also more likely to also undertake R&D. In this paper we expand the question to consider whether exporters also differ from non-exporters in the knowledge inputs used for R&D. Using data for UK firms we find that while in general this is so, non-exporters also involve themselves in international knowledge transfer.

JEL classification: F14, O32, O33

Keywords: Exporters, innovation, R&D, international knowledge transfer

Outline

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2. *Literature review*
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Non-Technical Summary

A recent area of debate within the field of firm levels responses to globalisation has been whether firms self select into export markets, or whether exposure to international markets brings any benefits to the firm. In this literature the weight of evidence is that direction of causation is from productivity to exporting. Drawing on the work from the literature on international knowledge transfer at the macro level in this paper we investigate whether these benefits are conditional on firm investments. In particular do exporters, because they are exposed to foreign individuals who may have different technical information or experience, use this information in the development of their successful innovations. We investigate this for a sample of UK firms.

From our analysis we generate a number of findings. Firstly, we find it possible to replicate existing evidence on international knowledge transfer for exporters using micro data: we find no evidence of a simple relationship between export status and international knowledge transfer. However, importantly we find that existing data can take us only so far on the question of international knowledge transfer. The split into exporting\non-exporting for example is too simplistic and cannot account for the geographic origin of information or allow for multiple channels used to transfer knowledge. Once we allow for such interactions the relationship between exporting and international knowledge transfer we find that while we can conclude that there is evidence of a difference in behaviour in international knowledge transfer for innovation between exporters and non-exporters, this relationship is not a simple positive one. Exporting to some regions can actually make it less, and in other cases no more, likely that a given combination of channel and origin are chosen. Non-exporters also transfer knowledge internationally, although it appears confined to a given set of channels and types of knowledge. In this sense our results agree with the conclusion of Keller that “the ongoing interaction with foreign firms and consumer seems to be a process of knowledge discovery that cannot be had from interacting only with other domestic firms” (Keller, 2004, p.65).

1 Introduction

Recognition of the importance of productivity, and therefore technology, as an explanation of cross-country income differences (Prescott, 1998; Hall and Jones, 1999; McGrattan and Schmitz, 1999), combined with the geographic concentration of R&D effort in a small number of countries[1] has led to growing interest in the manner through which innovations diffuse across space (Fagerberg, 1994). [2] When the transfer is across national borders this has become known as international knowledge transfer.

In his recent review of the empirical evidence Keller (2004) identifies two main channels through which domestic firms benefit from foreign R&D embodied in machinery and equipment, materials or individuals. These are FDI and international trade, with the strongest correlations generated using indicators of FDI or imports and country or industry level data (for example Coe and Helpman, 1995; Coe, Helpman and Hoffmaister, 1997; Lichtenberg and van Pottelsberghe de la Potterie, 1998; Keller, 2000; and Eaton and Kortum, 1999).[3] In this paper we add to that literature but focus on the role of exports as a channel for technology diffusion using micro (firm) data. As Keller (2004) notes, the current evidence for an association between exporting and knowledge transfer at the micro level is weak.

This conclusion is built on the evidence drawn from Bernard and Jensen (1999) and others (see Greenaway and Kneller, 2006, or Wagner, 2007, for a review) and successfully modelled by Melitz, (2003), Bernard et al. (2003) and Helpman et al. (2004) using a combination of heterogeneous firms and sunk entry costs. Multinational firms are more productive than exporters, who in turn are on average more productive than non-exporters, where this ordering occurs because the best firms self-select into the markets that they serve (both domestic and foreign). The ability of a firm to cover the sunk costs of market entry abroad and make positive profits is increasing in their productivity. In this literature the weight of evidence is that direction of causation is from productivity to exporting.

[1] Keller (2004) reports that the G-7 countries account for 84% of R&D expenditure (figure for 1995) compared to 64% per cent of world GDP.
[2] Interest in these topics developed out of the endogenous growth literature in the 1990s, see Grossman and Helpman (1991), River-Batiz and Romer (1991), Eaton and Kortum (1999, 2002),
[3] Indeed Keller (2004) notes the correlation would appear largely dependent on using macro data.

There exists however, a small number of studies that have suggested that firms might also benefit as a result of their exposure to international markets through exporting (the so called learning by exporting hypothesis). Typically the evidence is indirect: comparisons are made of firm characteristics (mostly their productivity) before and after new export market entry with non-exporting firms (or a sample of them controlling for selection effects). From this inference is then made whether learning through the development of new, or the imitation of previous technologies developed abroad, or some other factor such as reductions in inefficiency because of greater competition, were important.[4] A summary of the evidence from this literature might be that at best, support is specific to the context in which it has been considered: only firms with the right characteristics, determined by their age, export exposure, size or industry, benefit from their exposure to international markets (Greenaway and Kneller, 2006).

Consistent with the view that learning effects are not universal, more compelling evidence for their existence can be found in a few studies that analyse the investments that firms make in order to absorb information and expertise from abroad. This literature takes the view that the international diffusion of knowledge is neither inevitable nor automatic, but requires supporting investments in new technology. An important channel considered for this role has been investment in innovative activity. A number of studies have found that exporters are more likely to undertake R&D (Wakelin, 1998; Bleaney and Wakelin, 2002; and Roper and Love, 2002, for the UK; Bernard and Jensen, 2001, for the US; Aw et al., 2005, for Taiwan; Barrios et al., 2001, for Spain; and Baldwin and Gu, 2004, for Canada), although of these only Baldwin and Gu (2004), Solomon and Shaver (2005) and Aw et al. (2005) establish that causation also flows from exporting to R&D investment or outputs.

This paper adds to that literature by searching for evidence of a difference between exporters and non-exporters in the source of inputs used for innovation, where some of these are sourced from abroad. Specifically we ask whether exporters are more likely to draw on foreign technical information, experience and inputs in their successful innovations than non-exporters. This question is similar to those investigated for export firms in Baldwin and Gu (2004), Veugelers and Cassiman (2004), Criscuolo et al. (2005) and Wagner (2006). Focusing on exporting as a channel for knowledge transfer, Baldwin and

[4] A third channel often also considered is scale effect. Evidence from Tybout and Westbrook (1995) suggests that this may be an unimportant source of efficiency change however.

Gu (2004) investigate whether Canadian exporters are more likely to collaborate with foreign buyers than non-exporters in their R&D. In comparison Criscuolo et al. (2005), Wagner (2006) and Veugelers and Cassiman (2004) are somewhat broader and report on the use of information internal or external to the firm in R&D by UK and German firms and knowledge transfer between multinationals and their subsidiaries in Belgium respectively.

The greater contribution of the paper comes from the extension of the question to consider whether the international knowledge transfer that occurs because exporters have greater exposure to stock of technical knowledge in the countries they export to. This question is new and might be described as a strong version of the learning by exporting hypothesis: is there evidence of learning only from the export markets the firm serves? As new technologies have different amounts of codified versus tacit knowledge embodied with them (Teece, 1997) we also search whether these patterns of behaviour are consistent across all channels used for diffusion, or are exporters more likely to choose some channels over others? These include imported inputs and materials, person-to-person contact as well as joint ventures between domestic and foreign firms in R&D, which we label FDI. Our empirical investigation therefore links exporters with technology transfer using the channels for which the empirical evidence has traditionally been found to be strongest. This evidence is provided for a cross-section of UK firms over the period 1997 to 1999.

From our analysis we generate a number of findings. Firstly, we find it possible to replicate existing evidence on international knowledge transfer for exporters using micro data: we find no evidence of a simple relationship between export status and international knowledge transfer. However, importantly we find that existing data can take us only so far on the question of international knowledge transfer. The split into exporting\non-exporting for example is too simplistic and cannot account for the geographic origin of information or allow for multiple channels used to transfer knowledge. Once we allow for such interactions the relationship between exporting and international knowledge transfer we find that while we can conclude that there is evidence of a difference in behaviour in international knowledge transfer for innovation between exporters and non-exporters, this relationship is not a simple positive one. Exporting to some regions can actually make it less, and in other cases no more, likely that a given combination of channel and origin are chosen. Non-exporters also transfer knowledge internationally, although it appears confined to a given set of channels and types of knowledge. In this sense our results agree with the

conclusion of Keller that "the ongoing interaction with foreign firms and consumer seems to be a process of knowledge discovery that cannot be had from interacting only with other domestic firms" (Keller, 2004, p.65). That said, where we find a positive relationship between exporting and knowledge transfer there is some evidence that this occurs primarily from the regions that the firm exports to. While we cannot completely discriminate between self-selection versus learning using this data it would appear at least that there are instances where the results support a strong version of the learning by exporting hypothesis.

The rest of the paper is organised as follows. Section 2 reviews the literature. Section 3 the data and methodology and Section 4 the results. Section 5 of the paper concludes.

2 Literature Review

Empirical testing of the learning-by-exporting by exporting hypothesis at the micro level has come either in the form of an evaluation of the productivity performance of export and non-export firms, or a more direct study of the investments that firms make in order to start, or as a result of exporting.[5] This paper fits into that second strand, although we briefly review the evidence on both.

The literature on learning using information on productivity at the firm or plant level is now relatively large and covers many different country and time contexts (see Greenaway and Kneller, 2006, or Wagner, 2006, for reviews). For international knowledge transfer the basic hypothesis is that foreign customers or suppliers demand higher product standards but at the same time provide the information necessary to achieve them. This requires investment by firms in new equipment or R&D, which in turn leads to improvements in the quality of products or the manufacturing process and higher (measured) productivity as an output. The evidence for learning from this approach suggests that its effects are confined to a sub-set of firms or industries and lasts for a relatively short period of time (2-3 years). Firms that are young (Delgado *et al*. 2002; Fernandes and Isgut, 2005), highly exposed to export markets (Kraay, 1999; Castellani, 2002; Girma *et al*, 2004; Damijan *et al*., 2006) and in industries in which current exposure to foreign firms (through arms length trade and FDI) is low (Greenaway and Kneller, 2004) appear most likely to benefit.

[5] As Keller (2004) notes micro level evidence on international knowledge transfer is largely concentrated around two questions: the productivity impacts of exporting and spillovers from FDI.

A different approach to this question has come from the small literature studying the investments firms make to generate new knowledge or absorb those created elsewhere in order to enter export markets, or as a consequence of exporting. Here R&D has both a direct effect on the stock of knowledge and it facilitates the absorption of ideas generated by others, including those from abroad. Cohen and Levinthal (1989) describe this as the two faces of R&D. Again the literature falls into two main strands. The first strand considers whether exporters are more likely to make investments in R&D, with some considering whether this is to a greater extent than before they started exporting. The second strand takes perhaps a narrower definition of knowledge transfer and considers how exporters undertake their R&D activities and whether they now use foreign information or skills. Specifically how firms draw on foreign inputs to complement their internal R&D process. In the first strand exporting acts as an incentive to undertake R&D, while the second strand explores differences in the nature of the knowledge production function (Griliches, 1979) between exporters and non-exporters.

Of the relationships between exporting and R&D investigated, the most common finding is that firms involved in international trade are also more likely to undertake R&D.[6] See for example Wakelin (1998), Bleaney and Wakelin (2002) and Roper and Love (2002) for the UK, Bernard and Jensen (2001) for the US, Aw et al. (2005) for Taiwan, Barrios et al. (2001) and Solomon and Shaver (2005) for Spain and Baldwin and Gu (2004) for Canada.[7] Of these only Baldwin and Gu (2004), Solomon and Shaver (2005), Criscuolo et al. (2005) and Aw et al. (2005) provide evidence that causation also flows from exporting to R&D investment or outputs. Baldwin and Gu (2004) find that there is no statistical difference between the R&D intensity of exporters and non-exporters prior to their internationalisation, but there is following it, while for Spanish firms Solomon and Shaver (2005) find that exporting affects patent applications only with a 2 to 3 year lag. Along similar lines Criscuolo et al. (2005) report that globally engaged firms, including exporters have more innovations. Aw et al. (2005) take a very different approach recognising the interdependence of the export and R&D decision. They find for a panel of Taiwanese firms in the electronics industry that those that do not invest in R&D export have lower

[6] Here we focus on the micro level evidence of the relationship between exporting and R&D. There is a much larger literature relating R&D, productivity and global engagement more broadly defined. Examples within this literature include Coe and Helpman (1995), Coe *et al.* (1997) and Keller (2001a, 2002).

[7] In most cases these study the effect of R&D activities on export participation and the export intensity of firms.

productivity growth than those that just export, which in turn is lower than those firms that invest in both. They argue that these findings are consistent with an interpretation that R&D investments are necessary for firms to benefit from their exposure to international markets.

Evidence on differences in the knowledge production function between exporters and non-exporters is generally offered through anecdotes, case study and survey work (Westphal, 2002; Lopez 2004; Alvarez and Lopez, 2005; Van Biesebroeck, 2005; and Blalock and Gertler, 2004), where this choice reflects difficulties in collating the detailed information necessary to study the R&D production function for large numbers of firms or time periods. The general hypothesis tested here is that technical information external to the firm is an important input into the innovation process and that some of this comes from overseas customers or suppliers. [8]

The alternative approach has been to focus on a single input into the production process. Criscuolo et al. (2005) report on the use of information internal or external to the firm in innovation for the UK, in particular whether the type of external information follows along some vertical or horizontal linkage or is free from a university. They report that on average multinationals use information from a greater number of sources than exporters who in turn make more use of information external to the firm than non-exporters. In the case of multinationals it seems reasonable to assume that some of this is from affiliates abroad and is therefore international. This would then support evidence from Veuglers and Cassiman (2004) for Blegian. They find that subsidiaries of foreign multinationals located in Belgium are more likely to acquire technology internationally. Greater similarity to this paper is offered by the survey of Canadian firms in Baldwin and Gu (2004). Here the authors find that exporters are more likely to collaborate with foreign buyers than non-exporters in their R&D and that this is associated with the decision to start exporting. They can find no statistical difference in the periods before they became exporters in the extent to which these firms were likely to collaborate with domestic buyers in their R&D.

[8] Other evidence suggest that the internationalisation of R&D has become increasingly important over time. Using industry level data from the OECD, Bloom and Griffith (2002) report that UK R&D activity has

3 Empirical Methodology and Data

A common feature of the above literatures is the assumption that the learning by exporting hypothesis is fully captured by a separation of firms into exporters and non-exporters. One consequence of this has been that it is often difficult to establish the direction of causality between exporting and R&D, productivity or other firm characteristics. An alternative, consistent with the heterogeneity in the export strategies of firms recently described in Eaton, Kortum and Kramarz (2005) and Bernard, Jensen and Schott (2005), is to consider how firm behaviour differs according to the markets that they serve. This might be thought of as a stricter form of the learning by exporting hypothesis than that usually considered: the change in firm behaviour that exporting generates should be observed as a direct consequences of serving a particular export market.

Such a test is data demanding, requiring information not only on the destination of firm exports but also detailed information on firm actions that can be either tied to firm export decisions or from particular markets. Such data are not typically available, for example the most detailed large scale survey of which we are aware, the Community Innovation Survey commissioned originally by the EU and used by Veugelers and Cassiman (2004) and Curiscuolo et al. (2005), does not have information on export destination of the firm or the geographic origin of knowledge transfer flows used in R&D.

The data used in this study is taken from a survey of 128 firms with successful innovations in the South East of England in 1999/2000 by Simmie (2002). Unfortunately the detailed information necessary for a fuller test of the learning hypothesis comes at the price of a limited number of observations. Given the small number of observations it is important to consider the characteristics of the sample relative to the population of firms.

Firstly, there is an obvious geographical bias to the data, however research and Development activity, as in many other countries, is highly regionally concentrated within the UK.[9] The South East Region (including London) has the highest level of innovative activity within the UK and is amongst the five highest regional concentrations in Europe.[10] The firms selected for survey were based on evidence of successful product or process

become increasingly international, both in the amount of UK R&D being conducted abroad and foreign R&D activity in the UK.

[9] See for example Thus et al. (1996), Shefer and Frankel (2005) amongst others. [refs Harris & Li]

innovation, where this information was taken from the UK Department of Trade and Industry (DTI) and the UK Design Council.[11] The majority of the innovations studied came onto the market during the period 1997 to 1999.

Table 1 provides some detail on the size and age distribution of the firms surveyed in the sample along with their export status. The size, age and human capital measures available in the survey are categorical. There are five categories of firm size in the survey, although for the purposes of estimation we reduce these to three (less than 10 employees, 11-49 employees and 49+ employees). In a similar manner there are seven categories detailing the date of establishment of the firm in the survey, which we reduce to three (founded before 1980, founded between 1980 and 1990, and founded after 1990). In both cases this is done to ensure that there are a reasonable number of firms in each group. The main results of the paper are insensitive to changes in these categories. The measure of human capital used relates to the skill mix of the firm given by the proportion of workers with university level qualifications. Four categories of graduate employment are used (no graduates, 1-5 per cent of employees are graduates, 5-10 per cent are graduates and greater than 10 per cent). Again this choice is determined using information about the distribution of graduate employment across firms.

The mean values reported in Table 1 refer to the category in which the mean firm lies. Of the 128 respondents to the survey the mean firm has less than 10 employees, has less than 5 per cent of its employees with tertiary level qualifications and was established between 1980 and 1990. Of the respondents 18 per cent were multinational. This is slightly below the 22 per cent recorded using census of production data (ARD data) by Griffith, Redding and Simpson (2004 – OxREP).

The use of successful innovators and DTI information to identify innovators means therefore that the sample of firms available within the survey has an over-sampling of small firms relative to the population of firms. Within the population of firms sampled, some 80 per cent have employment less than 50 employees. Martin et al. (2002) report that some 36 per cent of all firms in the UK have less than 50 employees. Given that the probability of

[10] The others are the regions around Paris, Amsterdam, Milan and Stuttgart.
[11] Of the 310 firms within the sample frame 82 were no longer in existence at the point at which the survey took place, while the response rate was 56 per cent.

exporting, R&D and knowledge transfer are all increasing in firm size (see Girma et al., 2003 and Curicuolo et al., 2005) this may have the effect of making the knowledge transfer decisions of exporters and non-exporters in our sample more similar. The over representation of small firms leads us to caution from our results to that of firms.

Table 1: Summary statistics, mean values

	Total	Exporters	Non-exporters
Number of Obs.	128	77	51
Employment	<11	<11	<11
Percentage of employees that are graduates	1-5%	1-5%	1-5%
Date of establishment	1980-1990	1980-1990	1980-1990
Percentage that are multinational	17.97%	15.58%	21.57%

Control variables included in the regression are: firm size (<10, 11-49, >49), percentage of employees that are graduates (0%, 1-5%, 5-10%, >10%) firm age (<1980, 1980-1990, 1990-2000), multinational status, the firm is part of a regional cluster.

Within the sample 69 per cent of firms report that they export. This compares to 67 per cent for the UK using Companies House data in Girma et al. (2004), which has a bias towards large firms, and 44 per cent in the CIS-3, which is a representative sample of firms. The sample would appear consistent with the positive association between exporting and R&D found for the UK by Wakelin (1998), Bleaney and Wakelin (2002) and Roper and Love (2002).

Also contained within the survey is information on the destination of exports. As recently described in Eaton, Kortum and Kramarz (2005) for France and Bernard, Jensen and Schott (2005) for the US, firm export strategies are complex and a simple separation into exporters and non-exporters is a gross simplification of the data. For France Eaton et al. (2005) for example report that around 35 per cent of all firms export to one overseas country, close to 20 per cent export to 10 or more countries and only 1.5 per cent to more than 50 countries.

In our data exports are described according to whether they are sent to one of three destinations, Europe, North America and Elsewhere. Within our sample 83 per cent of exporters do so to the EU, 76 per cent to the US and 38 per cent elsewhere. Firms do not of course always export to single destinations and in Table 2 we describe more fully the number of firms that export to each of the seven combinations of export destinations

possible.[12] As Table 2 describes 32 per cent of firms export to only a single region, with the Europe (18 per cent) and North America (11 per cent) the most common. The remaining 68 per cent of export firms export to more that one region, although again this is mostly either to the Europe and North America (33 per cent) or to all regions (27 per cent). Given the small sample available within the formal estimations we aggregate this information into five groups: Europe only, North America only, North America & Europe, Other regions (alone or with Europe or North America) and All regions.

Table 2: Export Destinations

Export Destination	Obs.	Percentage
Europe	16	18.2
North America	10	11.4
Other	2	2.3
Euro & NA	29	33.0
Euro & Other	4	4.5
NA & Other	3	3.4
Euro, NA, Other	24	27.3
Total	*88*	*100.0*

Teece (1977) argues that new technologies have different amounts of codified versus tacit knowledge. It follows that the observed mode of knowledge transfer, trade, FDI, human contact etc., will depend on the type of knowledge that is relevant and how it is embodied (Keller, 2004). In the survey firms were asked to report on three different types of information or inputs used in the development of their innovation. These relate to collaboration, the use of external information and imported inputs. The questions are listed in Appendix A. The information contained in these measures of knowledge transfer are obviously direct. [13]

The first refers to the use of technical information with specialist individuals. Keller (2001) has previously discussed the role of person-to-person communication as a channel for knowledge diffusion at the industry level. With reference to that literature we label this as person-to-person transfer. The measure of knowledge transfer through inputs has a strong

[12] The survey contains a total of six destination categories: European Union, North America, Japan, Far East (excluding Japan), Australasia, Other. The numbers exporting to destinations other than the first two tended to be small in number and left too many empty cells were a more complete export destination matrix used.

[13] See Criscuolo et al. (2005) for an interesting discussion relating to the distinction between the measurement of actual knowledge transfer and that inferred from 'adjacent' activity (such as up stream or down stream transactions or geographic proximity). As in that paper, we recognise the self-reporting nature and therefore inherently subjective nature of this sample however.

similarity with the measure of imported goods used in the macro literature by Coe and Helpman (1995) and refined by Keller (1998, 2000), Xu and Wang (1999), Coe et al., (1997), Mayer (2001) and Henry et al. (2003). In reference to that literature we label it as imports. The measure of collaboration we use has similarities to that discussed in Baldwin and Gu (2004) and Veugelers and Cassiman (2004) and we describe it as FDI within R&D effort accordingly.[14] The balance of tacit versus codified knowledge is likely to increase as move from inputs, to person-to-person to FDI.[15]

According to the survey 74 per cent of firms seek information from outside the firm through person-to-person contact in the development of their successful innovation, the same number collaborated with other firms in their successful innovation, although only 30 per cent of these firms used partners that were located externally to the UK. The use of foreign inputs in the R&D process was the least popular of the channels considered, only 9 per cent of firms report that such inputs were used. [16]

As these raw numbers suggest international knowledge transfer operates across a number of different channels simultaneously (Keller, 2004). In Table 4 we summarise the way that firms transfer knowledge as an input into their innovations in our sample. As Table 4 shows, firms in our sample use both single and multiple channels for technology transfer. In particular firms appear to cluster around three options; choosing no information (40 per cent of firms choose this option), to source technical information through person-to-person contact (30 per cent), or through person-to-person contact in combination with FDI (16 per cent). In Table 4 we also report the percentage of firms which choose each of these combinations of channel for knowledge transfer that export. For example, of the 52 firms that do not undertake international knowledge transfer 59.6 per cent are exporters. This is lower than their distribution across the sample as a whole (69 per cent). Of the other channels, exporters are less prevalent amongst those that import in combination with person-to-person contact and FDI.

[14] These firms are not necessarily multinational in their production, indeed only half of the firms that use this source of information identify themselves as multinational.
[15] A limitation of this evidence is that it does not relate to the importance of the knowledge transferred.
[16] As in Veugelers and Cassiman (2004) we observe only that collaboration is taking place and infer that this involves the transfer of technical information.

Table 3: Channels through which international knowledge transfer occurs

Knowledge Transfer Channel	*Obs.*	*Percentage that export*
No Transfer	52	59.6
Person-to-person	38	71.0
FDI	1	100.0
Imports	5	80.0
Person-to-person & FDI	21	86.0
Person-to-person & Imports	5	60.0
FDI & Imports	3	67.0
Person-to-person & FDI & Imports	3	67.0

Further detail is also available within the data as to the geographic location from which information is sourced for two of the three channels considered, person-to-person contact and FDI, for the same three regional aggregates, Europe, North America and Other. This provides potentially rich detail on the international knowledge activities of firms; combining the three channels with the three destinations yields 128 different combinations of channel and location to explore. This number is by coincidence, the same as the number of observations within the sample.

Despite this array of possible combinations of channel and location in practice firms cluster within a small number of choices. There are just 32 of the 128 different combinations that are chosen in practice and many cells are populated by a single firm. To make progress we therefore aggregate up to consider the seven most common combinations of knowledge transfer, a residual category that includes all other knowledge transfer combinations and a ninth that includes all firms that undertake no international knowledge transfer. The percentage of firms in each of the nine cells is displayed in Table 4 below. As the table perhaps makes clear given the number of observation in the dataset there is a balance between a desire to push the data hard to reveal its patterns and pushing it too hard that there is not sufficient variation within each of the cells to identify differences in activity. Given the clustering of choices made in the Table we consider the auxillary question of trying to identify factors that might help to explain this clustering.

Table 4: Channels through which international knowledge transfer occurs

First Channel	*Location*	*Second Channel*	*Location*	*Percentage of Observations %*	*Percentage of Exporters %*
No transfer				*41*	*60*
Person-to-person contact	Europe			*2*	*33*
	North America			*6*	*63*
	Europe & North America			*9*	*91*
	Rest			*13*	*69*
Person-to-person contact	Any	FDI	Europe	*4*	*80*
	Any	FDI	North America	*6*	*88*
	Any	FDI	Rest	*5*	*86*
All other transfers				*14*	*72*

The formal analysis in the paper is conducted both using both probit and multinomial logit regression models of the probability that an exporter uses foreign information in their innovation, conditional on other firm as well as industry and regional characteristics. The firm level variables are whether the firm is a multinational and later in the paper we add indicators of firm size and levels of human capital. The industry level variables include whether the firm is part of a larger regional agglomeration of similar firms and the geographical location of the technical frontier. A similar set of control variables are used by Baldwin and Gu (2004). The specific equation estimated is a probit model that the firm undertakes knowledge transfer of the form

$$\Pr(D_{FINFO} = 1) = \phi(aEXP + \beta Z_i)$$

where D_{FINFO} is a 0/1 indicator of whether the firms used foreign information and EXP a 0/1 indicator of the export status of the firm. The firm and industry\regional covariates are included in Z.

The reported coefficients are all reported as marginal effects, the effect of a unit increase in the impendent variable on the probability that the dependent variable equals one when all other independent variables are held constant at their mean values. For zero-one variables

such as the export status of the firm the reported marginal effect is the effect of a change in the status of the variable from zero to one on the probability of the dependent variable.

The multinomial logit regression is based on the decision knowledge transfer matrix facing each firm which is described as the nine options in Table 4 above. All reported coefficients are expressed relative to not choosing international knowledge transfer. The empirical model takes the form:

$$\Pr ob(Y_{it} = j) = e^{\beta_j' x_{it}} \Big/ 1 + \sum_{k=1}^{8} e^{\beta_k' x_{it}}$$

where j equals 1 if firm i chooses person to person contact from Europe, 2 if it chooses person to person contact from North America, 3 if it chooses person to person contact from Europe and North America, 4 if it chooses person to person contact from somewhere else, 5 if firm i chooses person to person contact (from anywhere) and FDI from Europe, 6 if it chooses person to person contact (from anywhere) and FDI from North America, 7 if it chooses person to person contact (from anywhere) and FDI not from Europe or North America alone, and 8 if it chooses person to person contact, FDI and imported inputs. The omitted category is not choosing international knowledge transfer. The vector x_{it} consists of firm and industry characteristics.

4 Empirical Evidence

International Knowledge Transfer

The empirical strategy we adopt in the paper is to initially replicate as close as possible the type of specifications used within the current literature on international technology transfer and exporting at the micro level. That is we ignore initially the detail on the origin of information as well export destinations available to consider instead knowledge transfer through each of the identified channels (person to person, FDI and imports) separately and in aggregate, and the export status of the firm. In part this is driven by the non-representative nature of the sample. We then investigate the extent to which disaggregating the export indicator to account for differences in export destination changes the results before finally using as much of the information on channel and origin of knowledge transfer in the data.

According to Keller (2004) there is little support for a relationship between exporting and international knowledge transfer. To provide a comparator with this literature in Table 5 we report the results from a probit model for each of the technology transfer channels separately (Table 5, regressions 2-4) and where we aggregate across the three different channels under investigation (regressions 1) against a zero-one indicator of export status of the firm.

Given the sample size and to increase the probability of finding a correlation between exporting and international knowledge transfer we begin by including a small number of additional control variables in these regressions. We control only whether the firms is a multinational or not and whether it reports that there is a cluster of similar firms within its region. Lichtenberg and van Pottelsberghe de la Potterie, (1998) have previously found strong evidence that multinationals are an important channel for intertnationa knowledge transfer at the aggregate level, while Cassiman and Veuglers (2004) provide similar evidence at the micro level. Drawing on the literature of agglomeration effects (see Gorg and Greenaway, 2002 or Greenaway and Kneller, 2006, for summaries of the evidence as they relate to exporting), regional clusters were seen as less likely to be involved in international knowledge transfer.

The results from regression 1 are consistent with the evidence discussed in Keller (2004): we find no evidence that exporters are more likely to transfer knowledge across national borders than exporters for any of the channels considered. While firms that export from the UK may be more likely to be involved in R&D than non-exporters (Wakelin, 1998; Bleaney and Wakelin, 2002; and Roper and Love, 2002) it would appear the average exporters is no more likely to exploit these international links within the R&D process than non-exporters, at least for the small firms that constitute much our sample.

This contrasts with the result for multinationals firms in the Table who it would appear are more likely to transfer foreign knowledge on average (column 1) and in particular through person-to-person contact and through collaboration with others located abroad (FDI). Indeed the estimated marginal impact of being multinational and using foreign information is large at 35 per cent for person–to-person contact and 47 per cent for FDI (regressions 2

and 3). Consistent with the agglomeration literature we find little support for information spillovers within our sample.

Table 5: Probit model of participation in International Knowledge Transfer and exports

	(1)	*(2)*	*(3)*	*(4)*
Channel	*All channels*	*Person-to person*	*FDI*	*Imports*
Export Dummy	0.156 (1.61)	0.127 (1.29)	0.117 (1.53)	-0.012 (0.21)
Multinational	0.325 (2.77)**	0.351 (2.92)**	0.469 (4.34)**	-0.029 (0.40)
Regional cluster	0.031 (0.29)	0.079 (0.73)	-0.024 (0.29)	-0.127 (1.94)+
Observations	128	128	128	128

While insignificant, the point estimate on the export indicator in regression 1 is positive and very close to standard significance levels (it is significant at the 10.8 per cent level), suggesting that there may be some support for the data for the learning-by-exporting hypothesis for a sub-sample of firms. In Table 6 we re-estimate the results in Table 5 but exploit the information contained within the sample on the export destination of firms as a source of possible heterogeneity. As Bernard, Jensen and Schott (2005) and Eaton, Kortum and Kamarz (2005) identify export strategies and therefore the firms themselves can be diverse and therefore imposing a 0/1 structure to exporting may represent a very restrictive assumption on the behaviour of firms. As described in Section 3 firms tend to export to a small number of combinations of export destinations. Regression 2 therefore includes five groups of export destination: Europe only, North America only, North America & Europe, Other regions (alone or with Europe or North America) and All regions.

According to regression 2 firms that export to North America or to Other (and/or Europe and North America) are more likely to transfer knowledge internationally. It would appear that were such information available within the current literature stronger evidence for learning-by-exporting might have been uncovered, although in turn it raises the question of why these export destinations. There are also differences across the individual channels (regressions 2 to 4). Firms that export to Europe and North America or to Other regions (either alone or with Europe or North America) are significantly more likely to transfer knowledge through person to person contact, while those that export to Other regions (either alone or with Europe or North America) are also more likely to use FDI as a channel for knowledge transfer. These regressions strongly suggest that there are differences in the

choices firms make about international knowledge transfer according to where they export. In contrast, imports of intermediate goods for R&D are not significantly associated with exporting even when using more detailed export information.

Table 6: Probit model of participation in International Knowledge Transfer and exports

	(1)	(2)	(3)	(4)
Channel	*All channels*	*Person-to person*	*FDI*	*Imports*
Export to EU	0.059 (0.39)	0.050 (0.32)	0.081 (0.53)	-0.065 (0.75)
Export to NA	0.298 (1.97)*	0.088 (0.72)	0.134 (1.17)	0.058 (0.76)
Export to EU & NA	0.100 (0.86)	0.445 (2.60)**	0.143 (0.86)	Predicts Failure perfectly
Export to Other Or/& EU/NA	0.365 (2.31)*	0.285 (1.73)+	0.384 (2.27)*	-0.033 (0.32)
Export to All	0.078 (0.60)	-0.011 (0.08)	0.089 (0.81)	-0.009 (0.11)
Multinational	0.344 (3.03)**	0.390 (3.33)**	0.499 (4.57)**	-0.038 (0.51)
Regional cluster	0.058 (0.56)	0.115 (1.07)	-0.030 (0.35)	-0.135 (1.98)*
Observations	128	128	128	119

Additional Control Variables

While the above results are consistent with an interpretation of learning they might also describe self-selection. The positive association between exporting to particular destinations and international knowledge transfer identified in Table 6 might be explained by a correlation between the export status of the firm and some unobserved firm specific effect such as managerial ability. The best firms are able to overcome the sunk-costs associated with exporting to the greatest number of markets, in particular those where foreign firms operate close to the technical frontier such as the US or in markets that are further away from the UK (such that the marginal cost to the firm of serving those markets rises). Criscuolo (2005) report that globally engaged firms in the UK use a greater number of inputs in innovation, while Eaton et al. (2005) report a positive correlation between firm productivity and exporting to markets that are located further away.

We investigate these points in Table 7 by adding controls for firm and industry characteristics. To control for the location of the leading firms in the industry we use information in the survey on the location of the main centres of competition for the firm. Altogether 63 per cent of firms report that the greatest centres of competition are outside of

the UK, with the US (54 per cent) being the most likely centre for competition compared to the EU (38 per cent) and elsewhere (23 per cent).

The cross-section nature of the sample used in this study limits our ability to control for unobserved factors such as managerial ability through methods such as instrumental variable estimation.[17] Instead we add to the regression additional control variables that are likely to be strongly correlated with managerial ability such as firm size and measures of human capital and caution the conclusions from the paper on this point. Three measures of firm size, measured by the number of employees, are used: firms with employment less than 10, between 11-49, and greater than 49. Human capital is measured by the percentage ratio of graduates to total employment. Here there are four categories: 0%, 1-5%, 5-10% and 10+%. Within the regressions the effects of size and human capital are measured relative to the smallest (less than 10 employees) and least human capital intensive firms (no graduates).

In Table 7 we find little systematic variation in the probability of international knowledge transfer with the controls for other firm characteristics, a result that probably reflects the self-selection of the best firms into R&D and the tendency to over-sample small firms. More human capital intensive firms are more likely to transfer technology through FDI and importing intermediate goods, whereas large firms are less likely to import intermediate goods. There are no other significant correlations within the table.

Given the general inability of the firm and industry controls to explain any additional variation in the data, comparing across Tables 6 and 7 suggests little sensitivity of the export variables to the addition of other controls. In column 1 where we aggregate across all channels there is no longer a positive effect from exporting to North America and the probability of undertaking and international knowledge transfer, whereas there is now if the firm exports to North America and Europe. Similarly, in column 2 knowledge transfer through person to person contact is no longer positive correlated with exporting to the Other region.

[17] Selecting appropriate instruments is likely to be difficult owing to limited information given the structure of the data, while in turn the shape of the data-set also makes it likely that the results will be sensitive to the choice of instruments used.

Table 7: Multinomial logit regression of International Knowledge Transfer and Export Destination

	(1)	(2)	(3)	(4)
Channel	All channels	Person-to person	*FDI*	*Imports*
Export to EU	0.036 (0.22)	-0.034 (0.20)	0.023 (0.24)	0.005 (0.07)
Export to NA	0.054 (0.43)	-0.041 (0.31)	0.048 (0.64)	0.119 (1.60)
Export to EU & NA	0.340 (2.11)*	0.382 (1.98)*	0.056 (0.50)	
Export to Other Or/& EU/NA	0.302 (2.06)*	0.244 (1.42)	0.309 (2.03)*	-0.055 (1.04)
Export to All	0.050 (0.34)	-0.154 (0.90)	0.030 (0.33)	0.033 (0.51)
Multinational	0.327 (2.76)**	0.405 (3.16)**	0.418 (3.78)**	-0.014 (0.27)
Regional cluster	0.028 (0.25)	0.080 (0.70)	-0.030 (0.56)	-0.111 (2.46)*
Technical Frontier – EU	0.124 (1.19)	0.122 (1.10)	-0.054 (0.97)	0.021 (0.42)
Technical Frontier – NA	0.020 (0.18)	0.199 (1.62)	0.061 (0.96)	-0.038 (0.69)
Technical Frontier – Oth	0.056 (0.42)	-0.074 (0.53)	-0.019 (0.28)	-0.055 (1.12)
Size -employees 11-49	0.003 (0.02)	0.089 (0.71)	0.005 (0.08)	-0.084 (1.91)+
Size -employees 49+	0.081 (0.58)	0.123 (0.83)	-0.016 (0.22)	-0.079 (1.77)+
% graduates 1%-5%	0.236 (1.18)	0.323 (1.32)	0.964 (16.39)**	0.028 (0.38)
% graduates 5%-10%	0.237 (1.15)	0.217 (0.82)	0.982 (11.69)**	0.490 (2.50)*
% graduates 10+%	0.175 (0.80)	0.168 (0.61)	0.999 (.)	0.070 (0.77)
Observations	128	128	128	119

Other forms of International Knowledge Transfer

A simplifying assumption made in the analysis thus far is that firms export to and source technology from a single region. In the remainder of the paper we exploit more fully the information on international knowledge transfer available in the data.[18] Keller (2004) argues that the channel of technology transfer may depend importantly on the type of knowledge, tacit or codified, being transferred and that a number of channels may be used simultaneously.

[18] We do not add the additional control variables to these regressions as they lead to a number of the cells being perfectly identified.

To account for the complexity of the international knowledge transfer process we estimate a multinomial logit model allowing for seven of the most popular channels and origins of knowledge transfer. Following the information contained in Table 4 we consider the determinants of knowledge transfer through person to person contact only (from Europe, North America, Europe & North America and Other regions), through person-to-person contact and FDI together (with collaboration from Europe, North America or Other regions) and a residual category (all other forms of knowledge transfer). The remaining group of firms are not involved in international knowledge transfer and represent the omitted category in the regression model. These are regressed against the five export destination categories. The results from this process are presented in Table 8.

Perhaps the most striking feature of the evidence presented in Table 8 compared to those in Tables 5 and 6 is the appearance of significant negative coefficients on some of the export variables. Of the seventeen significant coefficients of exports estimated in Table 8 ten are negative. The results would tend to confirm that exporters behave differently to non-exporters in where they source technical information, but where exporting to some regions actually makes some combinations of channel and location less, not more likely. It follows of course that some types of international knowledge transfer are actually more likely to be made by non-exporters and international exposure in the destination of sales is not a prerequisite for international knowledge transfer. Again this may help to explain the insignificance of exporting as a channel for technology transfer in the current literature.

The significant negative coefficients in the Table are clustered predominantly in column 1 and to some extent in column 5 of Table 8, these relate to person-to-person contact from Europe and for person-to-person along with FDI with another European firm. UK exporters are more likely to choose to transfer knowledge from outside of Europe, and in column 1 this includes those firms that export only to Europe. This might suggest an association of the likelihood of knowledge transfer and exporting with distance. UK firms have in general better information on the technical expertise of other European firms and therefore exporting to that region brings little additional benefit compared to the information available to non-exporters. Keller (2004) summarises evidence from a number of studies that demonstrate a negative correlation between international knowledge transfer and distance (including Jaffe et al., 1993; Irwin and Klenow, 1994, Branstetter, 2001; Keller, 2002; Kneller, 2005).

The evidence from Table 8 is also capable of providing further insight into the results found in Table 6. For example the significance effect of exporting to Europe and North America and Other destinations on person to person contact in regression 2 is explained by person to person contact with Europe and North America (column 3 Table 8) and the residual person to person category (column 4 Table 8). Similarly the positive effect of exporting to Other destinations on the probability of knowledge transfer through collaboration in regression 3 (Table 5) is explained by EU FDI in combination with person to person contact (column 5 Table 8) and the residual person to person and FDI category (column 7 Table 8).

A second pattern within Table 12 is a difference in the knowledge transfer choices of firms that export to single versus multiple regions. It would appear to be the case that firms that export to single regions are in general more likely to choose to channel knowledge through FDI and person-to-person contact from that single region, whereas when the firm exports to multiple regions it is more likely to choose person-to-person contact only from that region. For example, firms that export to North America only are significantly more likely to choose person-to-person contact and North American FDI compared to non-exporters (column 6), whereas firms that export to Europe and North America or to those regions and/or the Other region are more likely to choose European-North American person-to-person contact (column 3) and the residual person to person category (column 4).

The difference when firms transfer knowledge from Europe is less evident in the Table, but becomes clearer when we alter the omitted category. Using person-to-person contact and Europe FDI (column 5) as the reference category the coefficient on export to Europe is significant and positive (t-statistic 11.07), whereas that on exporting to Europe and North America and to All regions are negative and significant (t-statistic, 7.84 and 7.31). Or alternatively if we choose exporting to Europe alone as the omitted export category we find that firms that export to North America and Europe are significantly less likely to choose person to person contact with another European firm.

If we interpret firms that choose more than one channel of knowledge transfer at a time as having a deeper level of international knowledge transfer then this result would contrast with that of Curiscuolo et al (2005) where more globally engaged firms are more likely to choose a deeper level of knowledge transfer. However, as in that paper, without

information on the detail of the strength of the knowledge flow claims on whether the association is positive or negative are perhaps premature. It might be for example that firms which export to multiple regions have higher productivity (Melitz, 2003) and this pattern reflects the capacity of firms to complete the R&D process 'in-house'.

In summary it would seem the relationship between international knowledge transfers and exporting is more complicated and more detailed than allowed for thus far in the analysis. It would also not appear to be described completely by either the weak or the strong version of the learning hypothesis: exporters behave differently to non-exporters, but not because they are always more likely to undertake international knowledge transfer, and there appears some link between export destination and the origin of technical information.

Table 8: Multinomial Logit Model of International Knowledge Transfer

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Channel	*Europe Person-to-person*	*North America Person-to-person*	*Europe & North America Person-to-person*	*Rest Person-to-person*	*Europe FDI & Person-to-person*	*North America FDI & Person-to-person*	*Rest FDI & Person-to-person*	*All other transfers*
Export to EU	-34.897 (39.70)**	0.672 (0.66)	1.059 (0.70)	0.153 (0.16)	1.756 (1.25)	0.805 (0.40)	-33.266 (26.16)**	-0.571 (0.46)
Export to NA	-34.579 (34.15)**	1.356 (0.96)	2.472 (1.53)	0.856 (0.67)	-33.299 (25.27)**	4.213 (2.75)**	3.740 (2.60)**	0.872 (0.65)
Export to EU & NA	-34.572 (42.35)**	-0.510 (0.42)	2.189 (1.90)+	-1.022 (0.87)	0.614 (0.41)	1.196 (0.87)	0.672 (0.49)	0.739 (1.04)
Export to Other Or/& EU/NA	2.735 (1.56)	2.259 (1.39)	3.182 (1.86)+	2.785 (2.15)*	3.523 (1.74)+	-32.003 (19.36)**	3.599 (1.90)+	-33.685 (29.72)**
Export to All	-34.276 (39.68)**	-34.191 (47.92)**	1.404 (1.07)	0.526 (0.64)	-33.674 (29.88)**	1.059 (0.82)	0.928 (0.69)	0.670 (0.88)
Multinat.l	-32.539 (33.98)**	1.051 (0.93)	1.387 (1.37)	1.221 (1.24)	1.508 (1.05)	4.221 (3.17)**	3.540 (3.53)**	1.621 (1.99)*
Regional cluster	1.107 (0.74)	0.775 (0.92)	0.247 (0.31)	0.597 (0.84)	1.033 (0.90)	-1.575 (1.66)+	0.493 (0.47)	-0.591 (0.85)
Observations	128	128	128	128	128	128	128	128

5 Conclusions

A recent area of debate within the field of firm levels responses to globalisation has been whether firms self select into export markets, or whether exposure to international markets brings any benefits to the firm. Drawing on the work from the literature on international knowledge transfer in this paper we investigate whether these benefits are conditional on firm investments. In particular do exporters, because they are exposed to foreign

individuals who may have different technical information or experience, use this information in the development of their successful innovations.

Our results are both capable of explaining existing results and providing some new insights into exporters and international knowledge transfer. In particular exporters are not always more likely to undertake some types of knowledge transfer than non-exporters, although there would appear clear differences in behaviour between these two sets of firms. If we split the learning-by-exporting hypothesis into a weak test – is exporting correlated with greater international knowledge transfer- and a strong test – knowledge transfer occurs only from the regions that firms export to then we might conclude there is evidence of both, depending upon the channel and origin considered.

References

Alvarez, R., (2004). 'Sources of Export Success in Small and Medium-Sized Enterprises: The Impact of Public Programs', *International Business Review*, Vol.13, pp. 383 - 400.

Alvarez, R. and López, R.A. (2005). 'Exporting and firm performance: Evidence from Chilean plants', *Canadian Journal of Economics*. Vol. 38, pp. 1384-1400.

Aw, B. Y. , Roberts, M.J., and Winston, T. (2005). 'The complementary role of exports and R&D investments as sources of productivity growth' *The World Economy*, (forthcoming).

Baldwin, J.R. and Gu, W. (2004). 'Trade liberalisation: Export-market participation, productivity growth and innovation', *Oxford Review of Economic Policy*, Vol. 20, pp. 372-392.

Barrios S., Görg, H. and Strobl, E. (2003). 'Explaining firms' export behaviour: R&D, spillovers and the destination market', *Oxford Bulletin of Economics and Statistics*, vol. 65, pp. 475-496.

Bernard, A., Eaton, J., Jensen, B. and Kortum, S. (2003). 'Plants and Productivity in International Trade', *American Economic Review*, Vol. 93, pp. 1268-1290.

Bernard, A. and Jensen, J.B. (1999). 'Exceptional exporters performance: cause, effect or both?', *Journal of International Economics*, Vol. 47, pp. 1-25.

Bernard, A. Jensen, J. and Schott, P. (2006). 'Importers, exporters and multinationals: A portrait of firms in the U.S. that trade goods', Tuck School of Business, mimeo.

Blalock, G. and Gertler, P.J. (2004). 'Learning from exporting revisited in less developed setting', *Journal of Development Economics*, Vol. 75, pp. 397-416.

Bleaney, M. F. and Wakelin, K. (2002). 'Efficiency, innovation and exports' *Oxford Bulletin of Economics and Statistics*, Vol. 64. pp. 3-15.

Bloom, N., and Griffith R. (2001) "The internationalisation of R&D" *Fiscal Studies* Vol. 22, Number 3, 337-355

Branstetter, L. (2001). 'Are knowledge spillovers international or intranational in scope? Microeconometric evidence from the U.S. and Japan' *Journal of International Economics*, Vol. 53, pp.53-79.

Castellani, D. (2002). 'Export behaviour and productivity growth: evidence from Italian manufacturing firms', *Review of World Economics / Weltwirtschaftliches Archiv*, vol. 138, pp. 605-628.

Coe, D., and Helpman, E. (1995) 'International R&D Spillovers', *European Economic Review*, 39, pp. 859-887.

Coe, D., Helpman, E., and Hoffmaister, A. (1997) 'North-South R&D Spillovers', *Economic Journal*, 107, pp. 134-149.

Cohen, W. and Levinthal, D. (1989). 'Innovation and learning: the two faces of R&D', *The Economic Journal*, Vol. 99, pp. 569-96

Criscuolo, C. Haskel, J. and Slaughter, M. (2005). 'Global engagement and the innovation activities of firms' NBER Working Paper 11479.

Damijan, J., Polanec S. and Prašnikar J. (2006). 'Self-selection, export market heterogeneity and productivity improvements: Firm level evidence from Slovenia', *The World Economy*, vol. 29, (forthcoming).

Delgado, M., Fariñas, J. and Ruano, S. (2002). 'Firm productivity and export markets: A non-parametric approach', *Journal of International Economics* vol. 57, pp. 397-422.

Eaton, J., and Kortum, S. (1999) 'International Patenting and Technology Diffusion: Theory and Evidence', *International Economic Review*, 40, pp. 537-570.

Eaton, J. Kortum, S. and Kramarz, F. 'An anatomy of international trade: Evidence from French firms' New York University, mimeo.

Fagerberg, J. (1994) 'Technology and International Differences in Growth Rates', *Journal of Economic Literature*, 32, pp. 1147-1175.

Fernandes, A. M. and Isgut, A., (2005). 'Learning-by-doing, learning-by-exporting, and productivity: evidence from Colombia' World Bank Policy Research Working Paper No. 3544.

Girma, S., Greenaway, D. and Kneller, R. (2004). 'Does exporting increase productivity? A microeconometric analysis of matched firms', *Review of International Economics*, vol. 12, pp. 855-866.

Görg, H. and Greenaway, D. (2004). 'Much ado about nothing? Do domestic firms really benefit from foreign direct investment?' *World Bank Research Observer*, vol. 19, pp. 171-197.

Girma, S., Greenaway, D. and Kneller, R. (2004). 'Does Exporting Lead to Better Performance: A Microeconometric Analysis of Matched Firms'. *Review of International Economics*, Vol. 12, No. 5, pp. 855-866.

Greenaway, D. and Kneller, R. (2004). 'Industry differences in the effect of export market entry: learning by exporting?', GEP Working Paper 2004/34.

Greenaway, D. and Kneller, R. (2006). 'Firm heterogeneity, exporting and foreign direct investment' (with David Greenaway), *The Economic Journal*. (forthcoming)

Griffith, Rachel, Steve Redding and Helen Simpson (2004) "Foreign Ownership and Productivity: New Evidence from the Service Sector and the R&D Lab" *Oxford Review of Economic Policy* G Vol. 20 No. 3, pp 440-456, Autumn 2004

Griliches, Z. (1979). Issues in assessing the contribution of R&D to productivity growth' *Bell Journal of Economics*, Vol. 28, pp. 1661-1707.

Grossman, G. and Helpman, E. (1991) Innovation and Growth and Growth in the Global Economy, MIT Press, Cambridge, MA.

Hall, R.E., and Jones, C.I. (1999) 'Why Do Some Countries Produce So Much More Output Per Worker Than Others' *Quarterly Journal of Economics*, 114, pp. 83-116.

Helpman, E., Melitz, M. and Yeaple, S. (2004). 'Export versus FDI', *American Economic Review*, Vol. 94, pp. 300-316.

Henry, M., Kneller, R. and Milner, C. (2003). 'Trade technology transfer and national efficiency in developing countries' GEP Working Paper No 32/2003.

Irwin, D. and Klenow, P. (1994). 'Learning spillovers in the semi-conductor industry' *Journal of Political Economy*, Vol. 102, pp. 1200-1227.

Jaffe, A., Trajtenberg, M. and Henderson, R. (1993). 'Geographic localization of knowledge spillovers as evidenced by patent citations' *Quarterly Journal of Economics*, Vol. 108, pp. 577-598.

Keller, W. (1998) 'Are International R&D Spillovers Trade-related? Analyzing Spillovers among Randomly Matched Trade Partners', *European Economic Review*, 42, pp. 1469-81.

Keller, W. (2000) 'Do Trade Patterns and Technology Flows Affect Productivity Growth?' *World Bank Economic Review*, 14 , pp.17-47.

Keller, W. (2001). 'Knowledge spillovers at the world's technology frontier' CEPR Working Paper 2815.

Keller, W. (2002) 'Geographic Localisation of International Technology Diffusion' *American Economic Review*, 92, pp. 120-42.

Keller, W. (2004) 'International Technology Diffusion' *Journal of Economic Literature*, 42, pp.752-782.

Kneller, R. (2005) 'Frontier Technology, Absorptive Capacity and Distance' *Oxford Bulletin of Economics and Statistics*, 67, pp. 1-24.

Kraay, A. (1999). 'Exports and economic performance: evidence from a panel of Chinese enterprises', *Revue d'Economie du Developpement*.

Lichtenberg, F.R., and van Pottelsberghe de la Potterie, B. (1998) 'International R&D Spillovers: A Comment', *European Economic Review*, 42, pp. 1483-91.

López, R. A. (2004). 'Self-selection into the export markets: A conscious decision?', mimeo. Department of Economics, Indiana University.

López, R. A. (2005). 'Trade and Growth: Reconciling the Macroeconomic and Microeconomic Evidence', *Journal of Economic Surveys*, Vol 19, pp. 623-648.

Martin, C., Martin, L. and Mabbett, A. (2002). 'SME Ownership succession – business support and policy implications, University of Central England mimeo.

Mayer, Jörg. (2001) 'Technology Diffusion, Human Capital and Economic Growth in Developing Countries', UNCTAD Discussion Paper #154, UNCTAD Geneva.

McGrattan, E.R., Schmitz, J.A., Jr. (1998) '*Explaining cross-country income differences*' Federal Reserve Bank of Minneapolis, Research Department Staff Report 250.

Melitz, M. (2003). 'The impact of trade on intra-industry reallocations and aggregate industry productivity', *Econometrica*, Vol 71, pp. 1695-1725.

Pack, H. (2000). 'Modes of technology transfer at the firm level' mimeo. University of Pennsylvania.

Prescott, E. (1998) 'Needed: A Theory of Total Factor Productivity', *International Economic Review*, 39, pp. 525-551.

Rivera-Batiz, L. and Romer, P. (1991) 'Economic Integration and Endogenous Growth', *Quarterly Journal of Economics*, 106, pp. 531-555.

Roper, S. and Love, J.H. (2002). 'Innovation and export performance: evidence from the UK and German manufacturing plants' *Research Policy*, Vol. 31, pp. 1087-1102.

Shefer, D. and Frenkel, A. (2005). 'R&D, firm size and innovation: and empirical analysis' *Technovation*, Vol. 25, pp. 25-32.

Simmie, J. (2002). 'Knowledge spillovers and reasons for the concentration of innovative SMEs' *Urban Studies*, Vol. 39, Nos. 5-6, pp. 885-902.

Solomon, R.M. and Shaver, J. M. (2005). 'Learning by exporting: new insights from examining firm innovation' *Journal of Economics and Management Strategy*, Vol. 14, pp. 431-460.

Teece, D. (1977). 'Technology transfer by multinational firms: the resource cost of transferring know-how', *Economic Journal*, Vol. 87, pp. 242-261.

Tybout, J. and Westbrook, M.D. (1995). 'Trade liberalization and dimensions of efficiency change in Mexican manufacturing industries' *Journal of International Economics*, vol. 31, pp. 53-78.

Van Biesebroeck, J. (2005) 'Exporting raises productivity in Sub-Saharan manufacturing plants', *Journal of International Economics*, (forthcoming).

Veugelars, R. and Cassiman, B. (2004). 'Foreign subsidiaries as a channel of international technology diffusion: Some direct firm level evidence from Belgium', *European Economic Review*, Vol. 48, pp. 455-476.

Wagner, J. (2006). 'International firm activities and innovation: Evidence from knowledge production functions for German firms' Max-Planck-Gesellschaft Working Paper 1506.

Wagner, J (2007). 'Exports and productivity: a survey of the evidence from firm level data'. *The World Economy*, vol. 29 (forthcoming).

Wakelin, K. (1998). 'Productivity growth and R&D expenditure in UK manufacturing firms' GEP Working Paper

Xu, B. and Wang, J. (1999) 'Capital Goods Trade and R&D Spillovers in the OECD', *Canadian Journal of Economics*, 32, pp. 1258-1274.

Appendix A:
Innovation Clusters in London and the South East. Simmie (2002).

International External Collaboration: This identified through the two questions
Did you have any external collaborators in the development of your innovation? And where were they located?

International Information through person to person contact: This is identified through the answers to two questions
What were the main types of international experience from outside of your firm that you made use of in the development of your innovation? Where did you obtain this international experience for your innovation?

Imported Inputs from Overseas: Again this is identified through two questions.
Approximately what percentage of the final technological input to the innovation is bought in from external suppliers? Approximately what percentage of the main suppliers to your innovation are located in the following areas?