Exporters and the Role of International Knowledge Transfer in Innovation: Evidence from UK firms

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Abstract:

Within the recent literature studying participation in international markets using micro level data a small number have suggested that firms might benefit from their exposure to international markets, the so called learning hypothesis. This literature takes the view that the international diffusion of knowledge is neither inevitable nor automatic, but requires investments in new technology. 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 way that they conduct their R&D innovations. Whether exporters, because they are more orientated to foreign markets, are more likely to draw on technical information and experience from abroad than non-exporters in their successful innovations. Using data for UK firms we find evidence that this is the case, although it differs according to the form of knowledge sharing that takes place.

JEL codes:

Keywords:

Section 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 with 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 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, 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 direction of causation is firmly 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).[4] 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 imitation of new technologies developed abroad, or some other factor such as reductions in inefficiency because of greater competition, were important.[5] 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 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. This evidence for international knowledge transfer is direct. Are exporters more likely to draw on foreign technical information, experience and inputs in their successful innovations than non-exporters? We then extend the question further to consider whether this occurs because exporters have greater exposure to stock of technical knowledge in the countries they export to, or whether it

[4] Ederington and McCalman (2004) develop a model of firm heterogeneity consistent with this outcome. Heterogeneity is a consequence of the decision of some firms to start to export.
[5] 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.

depends on them being a exporter more generally. Can we find evidence of a direct contact into the markets they source technical knowledge?

As new technologies have different amounts of codified versus tacit knowledge embodied with them (Teece, 1997) we also search whether this is consistent across all channel 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.

Some of these questions are similar to those investigated for export firms in Baldwin and Gu (2004), while Veugelers and Cassiman (2004) and Criscuolo et al. (2005) focus on knowledge flows in R&D investment but not the location or type of technology transfer. Baldwin and Gu (2004) investigate one part of the levels of technology transfer considered here; whether Canadian exporters are more likely to collaborate with foreign buyers than non-exporters in their R&D. Criscuolo et al. (2005) report on the use of information internal or external to the firm in R&D by UK firms distinguishing between the mode of engagement in international markets, but do not describe whether the location for the source of this information is domestic or foreign, while Veugelers and Cassiman (2004) describe knowledge transfer between multinationals and their subsidiaries in Belgium.

Our results suggest:

- Existing data can take us only so far on the question of international knowledge transfer. The split into exporting\non-exporting is too simplistic and cannot account for the geographic origin of information or allow for multiple channels for transfer.
- We can 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.
- We find value in extending the current literature and identifying where firms export to, the destination of exports is important.
- We find value in extending the current literature and including information on the origin of technical information used in R&D and for allowing the transmission of

knowledge from multiple origins and channels (person-to-person contact, FDI and imports).

- Overall we conclude that there is evidence of a difference in behaviour in international knowledge transfer for innovation between exporters and non-exporters, but this relationship is not a simple positive one. Exporting to one region can make it more or less likely will source information from a different region or channel than non-exporters.
- We might 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. We find evidence of both, depending upon the channel and origin considered.

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.

Section 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.[6] 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

[6] 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.

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.

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 entering export markets, or as a consequence of exporting. Here R&D has both a direct effect on the stock of knowledge and facilitates the absorption of ideas generated by others, including those from abroad.[7] 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 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.[8] 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.[9] 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)

[7] See also Cohen and Levinthal (1989).
[8] 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).
[9] In most cases these study the effect of R&D activities on export participation and the export intensity of firms.

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 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. [10]

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

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

periods before they became exporters in the extent to which these firms were likely to collaborate with domestic buyers in their R&D.

Section 3: Empirical Methodology and Data

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). Research and Development activity, as in many other countries, is highly regionally concentrated within the UK.[11] 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.[12] The firms selected for survey were based on evidence of successful product or process innovation, where this information was taken from the UK Department of Trade and Industry (DTI) and the UK Design Council.[13] 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

[11] See for example Thus et al. (1996), Shefer and Frankel (2005) amongst others. [refs Harris & Li]
[12] The others are the regions around Paris, Amsterdam, Milan and Stuttgart.

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 these innovators means that the sample of firms available within the survey has an over-sampling of small 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 exporters are on average larger than non-exporters (Girma et al., 2003) this may have the effect of making the exporters and non-exporters we consider more similar.

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. Of these exporters, 83 per cent export to the EU, 76 per cent to the US and 38 per cent elsewhere. In Table 2 we describe more fully the export destinations of firms. As Table 2, 32 per cent of

[13] 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.

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). 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
Rest	2	2.3
Euro & NA	29	33.0
Euro & Rest	4	4.5
NA & Rest	3	3.4
Euro, NA, Rest	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). If the relevant knowledge is codified in new equipment or materials then it is likely that the channel of transfer will follow through trade in goods. In contrast if it is the tacit elements of technology that are important to the firm then the channel of knowledge transfer will change and it is likely human contact becomes more important.

In the survey firms were asked to report on three different channels for knowledge transfer. The information contained in these measures of knowledge transfer are obviously direct. [14] The first, and our main measure, 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 other two channels questioned in the survey are the use of foreign inputs (capital and materials) in innovation and the

[14] 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.

collaboration with foreigners in innovation.[15] The measure of knowledge transfer through inputs has a strong 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.[16] The balance of tacit versus codified knowledge is likely to increase as move from inputs, to person-to-person to FDI.[17]

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. Of these firms 67 per cent (52 per cent of the population of firms) report using individuals located overseas. The table shows that of the 61 firms that did not seek information from overseas 38 per cent were non-exporters and 62 exporters, whereas of the 67 firms that did seek such information 75 per cent were exporters and 25 per cent not. Knowledge transfer can be further broken into the location from which the information was sourced. Of all firms in the sample 25 per cent used information sourced from the EU, 35 per cent from North America and 22 per cent from elsewhere. Overall, exporting seems to be positively associated with the transfer of technical information across borders through person-to-person contact.

Table 3: Number of firms reporting exporting and transfer foreign information through person-to-person contact

Export	No Foreign information	Yes Foreign information	*Total*
Non-exporter	23	17	*40*
Exporter	38	50	*88*
Total	*61*	*67*	*128*

Of the other levels of knowledge transfer considered in the paper we find that 74 per cent collaborated with other firms in their successful innovation, but only 30 per cent of these firms used partners that were located externally to the UK.[18] The use of foreign inputs in the

[15] These measures of knowledge transfer refer to the direct access and use of knowledge from abroad. Indirect effects through spillovers due to the co-location of foreign firms in the UK are not captured by these measures.
[16] 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.
[17] A limitation of this evidence is that it does not relate to the importance of the knowledge transferred.
[18] As in Veugelers and Cassiman (2004) we observe only that collaboration is taking place and infer that this involves the transfer of technical information.

R&D process is even less popular, only 9 per cent of firms report that such inputs were used. There appears less of a clear correlation with exporting for this measures. Of the firms that use FDI to transfer knowledge 82 per cent are exporters, while for imports it is 69 per cent, exactly in line with their distribution in the sample as a whole.

As Keller (2004) concludes in his review, international knowledge transfer is likely to operate across a number of different channels simultaneously. 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 that choose each combinations of knowledge transfer channels 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.

Table 4: 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

While the above is supportive of the view that export firms are more likely to source information from abroad compared to non-exporting firms, particularly through person-to-person contact and FDI, we also perform more formal analysis of this question by controlling for other potentially important covariates. For the question of international knowledge transfer we estimate a both probit and multinomial logit regression models of the probability that an exporter uses foreign information in their innovation conditional on other firm characteristics 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.[19] 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.

{multinomial logit model)

Section 4: Empirical Evidence

International Knowledge Transfer

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 of technology transfer where we aggregate across the three different channels under investigation. This indicator is equal to zero if the firm does not transfer information or inputs from abroad and equal to one when it is does. In regression 1 we regress this against an indicator of whether the firm exports or not, while in regression 2 we exploit the information contained within the sample on the export destination 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,

[19] ~ have previously shown that innovation is affected by the regional clustering of firms. This may likely to lower the probability that the firm draws on knowledge from outside of the country.

North America only, North America & Europe, Other regions (alone or with Europe or North America) and All regions.

To increase the probability of finding a correlation between exporting and international knowledge transfer we include as few as possible 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. 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 they are not more likely to exploit these international links within the R&D process. This contrasts with the result for multinationals firms, who are more likely to transfer foreign knowledge in Table 5. Indeed the estimated marginal impact of being multinational and using foreign information is large at 38 per cent. Consistent with the agglomeration literature we find little support for information spillovers within our sample.

While insignificant, the point estimate on the export indicator in regression 1 is positive and very close to significance (it is significant at the 10.8 per cent level), suggesting that there may be some support in the data for the learning-by-exporting hypothesis for a sub-sample of firms. Within the current literature typically firms can be separated only into whether they export or not, a zero-one indictor. As Melitz (2003), Eaton, Kortum and Kamarz (2005) identify the export strategies of firms and therefore the firms themselves can be diverse and as such a zero-one indicator of export status may be a restrictive assumption. We investigate this point in Table 5.

It would appear that were such information available within the current literature stronger evidence for learning-by-exporting might have been uncovered. 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. There are differences according in the behaviour of firms in their choices about international knowledge transfer according to where they export.

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

	(1)	(2)
Channel	*All channels*	*All channels*
Export Dummy	0.156 (1.61)	
Export to EU		0.059 (0.39)
Export to NA		0.298 (1.97)*
Export to EU & NA		0.100 (0.86)
Export to Other Or/& EU/NA		0.365 (2.31)*
Export to All		0.078 (0.60)
Multinational	0.325 (2.77)**	0.344 (3.03)**
Regional cluster	0.031 (0.29)	0.058 (0.56)
Observations	128	128

International Knowledge Transfer Through Person-to-person Contact

According to the summary statistics in Table 4, of the firms that are involved in international knowledge transfer 89 per cent do so through person-to-person contact. In Table 6 we test whether the evidence for knowledge transfer in Table 5 is derived from the relationship of this channel with exporting. The results from this regression, reported as regression 1 in Table 6, suggest not. While exporting is again positively correlated with international knowledge transfer, the coefficient on exporting is now further from significance at standard levels.

Again there would appear to be additional value in exploiting the level of information available within survey data of the type used here to study this question however. When we allow for differences according to where the technical information was sourced through

person-to-person contact the exact relationship with exporting is found to differ across regions (Table 6 regressions 2-4).

The conclusion in Table 6 answer would appear to be that while there is again evidence that exporters behave differently to non-exporters, it is not the case that only those firms that export to a given region are more likely to source technology from there. In this sense the results offer mixed evidence in support of a strict learning by exporting hypothesis: do exporters source information only from the regions that they export to. This is most obvious in the case of person-to-person with other firms from Europe (regression 2 Table 5). Here we find that firms that export to Europe alone are no more likely to channel technical information from there, whereas if they export to Europe and North America and other regions (which may include Europe in addition) they are more likely to do so. Interestingly the coefficient for multinational status of the firm is insignificant only when knowledge transfer is from Europe.

In contrast, it would appear that the destination of export sales is a much more important predictor of where the firm sources information from outside of the EU. The probability that a firm sources technical information through person-to-person contact from North America and Other regions is strongly predicted by whether the firm exports to that region or not (regressions 2 and 3 Table 6), although in the case of North American, and in contrast to European knowledge transfer, not if the firm exports to Europe & North America.

Table 6: Probit model of participation in International Knowledge Transfer

	(1)	(2)	(3)	(4)
Channel	*Person-to-person*	*Europe Person-to-person*	*North America Person-to-person*	*Other Person-to-person*
Export Dummy	0.127 (1.29)			
Export to EU		-0.070 (0.49)	0.188 (1.23)	-0.092 (0.81)
Export to NA		0.147 (0.91)	0.436 (2.50)*	0.107 (0.71)
Export to EU & NA		0.194 (1.69)+	0.158 (1.23)	-0.114 (1.16)
Export to Other Or/& EU/NA		0.367 (2.04)*	0.283 (1.42)	0.376 (2.19)*
Export to All		0.118 (0.93)	0.227 (1.68)+	0.040 (0.38)
Multinational	0.351 (2.92)**	0.129 (1.26)	0.313 (2.62)**	0.224 (2.13)*
Regional	0.079	0.173	-0.005	0.034

cluster	(0.73)	(1.83)+	(0.05)	(0.40)
Observations	128	128	128	128

Notes: Robust z statistics in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%
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.

A simplifying assumption made in the analysis thus far is that firms export to and source technology from a single region . In Table 7 we describe the sources of technical information through person-to-person contact within the data x. As Table 7 shows firms frequently draw on technical information from a number of different regions. Of the 67 firms that source technical information from abroad, 36 firms (54 per cent) choose to draw information from a single location and 31 (46 per cent) choose multiple locations. When firms choose knowledge from a number of different regions it tends to be the case that they do so from Europe & North America.

Table 7: Origins of Technical Information through person-to-person contact

Knowledge Transfer Origin	**Obs.**	**Percentage**
Europe	10	14.9
North America	16	23.9
Other	10	14.9
Europe & NA	13	19.4
Euro & Other	2	3.0
NA & Other	8	11.9
Euro, NA, Other	8	11.9
Total	*67*	*100.0*

To control for the interdependency between the regions from which technology might be sourced we estimate a multinomial logit model. Given the relatively low number of firms that transfer technology through person-to-person contact from regions other than Europe or North America we choose to aggregate together the decision to export to or transfer technology from non EU or North American export destinations, although we retain the group that choose expert information from all these regions (labelled All regions). The results from this exercise are reported in Table 8. The omitted category is not choosing international information transfer.

Perhaps the most striking feature of the evidence presented in Table 8 compared to those in Table 6 is the appearance of significant negative coefficients on some of the export variables.

Exporters behave differently to non-exporters in where they source technical information, but it is not the case they are always more likely to do so for a given region. Where the firm exports to appears to matter. For example, according to Table 8 firms that export to Europe are no more likely to source technical information than non-exporters, and are significantly less likely to do so from Europe, North America and Other regions simultaneously.

The evidence from Table 8 is also capable of providing further insight into the results found in Table 6. The significantly higher probability that a firm exports to Europe & North America and transfers technology from Europe found in Table 8 (column 1) is explained by a failure to account fully for the interdependency between sources of technical information. Firms that export to North America & Europe are actually significantly less likely to source information from Europe only, but consistent with the learning-by-exporting hypothesis, are more likely to source information from Europe & North America within the same innovation.

Similarly, the strong evidence that firms that export to the North America are more likely to source technology from that region in Table 6 would again appear sensitive to the use of the multinomial logit model. According to the results in column 2 of Table 8 the probability of technology transfer from North America is no more or less likely for firms that export there. In contrast, technology transfer from North America & Europe together (column 3) is strongly associated with exporting in general. According to this regression, firms that export to North America, or Europe & North America, or to other regions (alone or with Europe and North America) are all significantly more likely to source information from Europe and North America together. Finally, consistent with the evidence in Table 6, the probability that the firm transfers knowledge from other regions (alone or in combination with Europe or North America) or from all regions is positively correlated with exporting to those regions.

Table 8: Multinomial logit regression of International Knowledge Transfer and Export Destination

	(1)	(2)	(3)	(4)	(5)
Channel	*Europe Person-to-person*	*North America Person-to-person*	*Europe & North America Person-to-person*	*Other Or/& EU/NA Person-to-person*	*All regions Person-to-person*
Export to EU	-0.410 (0.34)	0.971 (1.14)	0.947 (0.61)	-0.344 (0.36)	-31.116 (27.85)**
Export to NA	-31.654 (40.45)**	1.449 (1.35)	2.862 (2.11)*	0.972 (0.92)	2.142 (1.39)
Export to EU	0.245	0.143	2.254	-0.864	0.556

& NA	(0.29)	(0.16)	(2.03)*	(0.98)	(0.37)
Export to Other Or/& EU/NA	2.173 (1.39)	1.876 (1.22)	3.441 (1.99)*	2.822 (2.31)*	3.586 (1.87)+
Export to All	-0.935 (0.68)	-0.388 (0.44)	0.938 (0.67)	-0.758 (0.86)	1.979 (1.56)
Multinational	1.426 (1.38)	1.775 (2.25)*	1.986 (2.31)*	2.436 (3.13)**	1.008 (0.95)
Regional cluster	0.972 (1.31)	0.101 (0.14)	0.560 (0.78)	0.207 (0.29)	1.093 (1.16)
Observations	128	128	128	128	128

Additional Control Variables

Of the origins for the technical information used in successful innovation by UK firms in Table 8 that from Europe & North America appear distinct, it is positively correlated with exporting to a number of destinations, in particular outside of Europe. One possible explanation for this result if that firms are targeting geographic locations in which firms that are closest to the technological frontier operate for their industry, although why exporters are more successful at this if they are not exploiting some sort of information advantage over non-exporters is not clear within this argument. A second, is that the export status of the firm may be correlated with 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. Against this it is now clear why some of the associations found thus far would be negative within this argument. Criscuolo (2005) report that globally engaged firms in the UK use a greater number of inputs in innovation.

We investigate these points in Table 9 and 10. 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 results from this exercise are reported in Table 9.

The cross-section nature of the sample used in this study limits our ability to control for unobserved factors through methods such as instrumental variable estimation.[20] 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. 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). The results from this exercise are reported in Table 9.

Comparing across Tables 8 and 9 suggests some sensitivity of the export variables to the addition of controls for the location of the technical frontier, most noticeably when technology transfer is from Europe and North America combined, although the remaining significance of a number of the export indicators suggests that they provide only partial explanations for the results found thus far.

In Table 8 the probability that firms that export to Europe & North America and Other regions are no longer more likely to seek technical information from Europe and North America, although firms that export just to North America are more likely to do so. This would appear to suggest that the location of firms that operate close to the technical frontier has some importance in this decision. The measures of the location of the leading-edge firms offer some support to this view. The indicator for North America and other regions as the location for the technical frontier is significant when technology is sourced from North America and All Regions respectively. However, it is insignificant in the remaining regressions, and somewhat unexpectedly North America as the location of the technical frontier is positively correlated with the probability the firm will source technical information from Europe.

Table 9: Multinomial logit regression of International Knowledge Transfer and Export Destination

	(1)	(2)	(3)	(4)	(5)
Channel	*Europe Person-to-*	*North America*	*Europe & North*	*Other Or/& EU/NA*	*All regions Person-to-*

[20] 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.

	person	*Person-to-person*	*America Person-to-person*	*Person-to-person*	*person*
Export to EU	-0.751 (0.61)	0.626 (0.66)	0.502 (0.32)	-0.445 (0.43)	-37.693 (26.52)**
Export to NA	-39.346 (40.96)**	0.913 (0.83)	2.478 (1.92)+	0.758 (0.65)	2.276 (1.23)
Export to EU & NA	-0.353 (0.36)	-0.377 (0.46)	1.686 (1.47)	-1.100 (1.22)	0.848 (0.51)
Export to Other Or/& EU/NA	1.128 (0.70)	1.083 (0.70)	2.714 (1.56)	2.576 (2.02)*	4.399 (1.88)+
Export to All	-1.784 (1.30)	-1.209 (1.21)	-0.056 (0.03)	-1.022 (1.07)	2.800 (1.60)
Multinational	1.492 (1.15)	1.956 (2.14)*	2.218 (2.18)*	2.468 (2.78)**	0.357 (0.34)
Regional cluster	0.603 (0.80)	-0.008 (0.01)	0.509 (0.61)	0.065 (0.09)	1.275 (1.08)
Technical Frontier – EU	-0.171 (0.20)	0.419 (0.71)	1.108 (1.35)	0.219 (0.35)	-0.333 (0.30)
Technical Frontier – NA	2.724 (2.37)*	1.390 (2.21)*	1.235 (1.17)	0.274 (0.35)	-1.373 (1.22)
Technical Frontier – Oth	0.332 (0.40)	-0.982 (1.13)	-0.949 (0.94)	0.089 (0.10)	1.990 (2.13)*
Observations	128	128	128	128	128

In Table 9 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. More human capital intensive firms are more likely to transfer technology from Europe, Other regions and All Regions together, while bigger firms are more likely to transfer technology from Europe and North America. The addition of these controls also has little impact on the results found in Table 9 and changes none of the main conclusions.

Table 10: Multinomial logit regression of International Knowledge Transfer and Export Destination

	(1)	(2)	(3)	(4)	(5)
Channel	*Europe Person-to-person*	*North America Person-to-person*	*Europe & North America Person-to-person*	*Other Or/& EU/NA Person-to-person*	*All regions Person-to-person*
Export to EU	-0.323 (0.24)	0.469 (0.43)	-0.139 (0.09)	-0.565 (0.58)	-32.377 (16.75)**
Export to NA	-33.152 (31.12)**	1.041 (1.01)	3.169 (2.20)*	0.651 (0.52)	2.034 (1.05)
Export to EU & NA	0.002 (0.00)	-0.446 (0.53)	1.317 (1.00)	-1.455 (1.80)+	0.186 (0.11)
Export to Other Or/& EU/NA	0.827 (0.47)	1.099 (0.66)	2.172 (1.02)	2.544 (2.06)*	4.040 (1.64)
Export to All	-1.184 (0.78)	-1.395 (1.28)	-0.647 (0.35)	-0.939 (0.90)	2.628 (1.36)
Multinational	1.738	2.069	2.216	2.494	0.921

	(1.09)	(2.26)*	(2.18)*	(2.62)**	(0.82)
Regional cluster	0.612 (0.71)	0.134 (0.18)	0.535 (0.72)	0.020 (0.03)	1.484 (1.17)
Technical Frontier – EU	0.237 (0.24)	0.448 (0.79)	1.365 (1.39)	0.456 (0.63)	0.242 (0.18)
Technical Frontier – NA	2.185 (1.84)+	1.440 (2.17)*	1.019 (0.86)	0.160 (0.19)	-1.836 (1.22)
Technical Frontier – Oth	0.916 (1.09)	-1.155 (1.33)	-1.127 (1.05)	-0.259 (0.28)	1.935 (1.60)
Size -employees 11-49	-0.181 (0.19)	-0.164 (0.14)	2.239 (1.88)+	-0.069 (0.09)	-0.139 (0.11)
Size -employees 49+	-0.264 (0.18)	0.743 (0.78)	2.616 (2.13)*	-0.933 (0.81)	2.442 (1.60)
% graduates 5%-10%	19.392 (17.94)**	1.015 (0.44)	0.489 (0.19)	21.023 (18.34)**	24.158 (11.38)**
% graduates 10+%		0.243 (0.10)	-1.066 (0.42)		-9.488 (6.05)**
% graduates 1%-5%	19.023 (15.67)**	0.106 (0.04)	-0.801 (0.30)	21.783 (16.05)**	
Observations	128	128	128	128	128

Other forms of International Knowledge Transfer

In the remainder of the paper we exploit the full information on international knowledge transfer available in the data. So far we focus on one particular type of international knowledge transfer, that of technical expertise, albeit the most common form within this data set. It is not the only form of interaction and knowledge sharing that occurs between firms however. Indeed Keller (2004) argues that the channel of technology transfer may depend importantly on the type of knowledge, tacit or codified, being transferred. The evidence presented in Table 4 above suggests that collaborative agreements with firms located abroad form a second popular type of channel for knowledge transfer in the UK, in particular when undertaken with transfer through person-to-person contact. The final channel considered, the of importing important inputs necessary for innovation is adopted by only around 9 per cent of firms.

Table 11 breaks down the information on collaborative agreements by region. As can be seen to the extent that collaborative agreements take place they tend to be with a single region, 72 per cent of agreements are of this type. The most popular collaborative agreement across multiple regions is that between North America and Other regions, 14 per cent of firms choose this option.

Table 11: Collaborative Agreements by Region

Knowledge Transfer Origin	Observations	Percentage
Europe	7	25.0
North America	8	29.0
Other	5	18.0
Euro & NA	2	7.0
Euro & Other	0	0.0
NA & Other	4	14.0
All Regions	2	7.0
Total	*28*	*100.0*

To account for the complexity of the international knowledge transfer process we extend the multinomial logit approach used above, allowing for seven of the most popular channels and origins of knowledge transfer and a residual category. Following the information in Tables 4 and 11 and the empirical evidence above 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. The results from this process are presented in Table 12.

Table 12 reinforces the main messages drawn already from the paper a) that exporting matters, although not always positively and b) that there the relationship between knowledge transfer is more complicated than typically allowed for. Of the seventeen significant coefficients estimated in Table 12 ten are negative. Exporting to some regions makes it less likely the firm chooses to transfer knowledge compared to firms that do not export. The relationship between international knowledge transfer and exporting is complex.

These negative coefficients are clustered predominantly in columns 1 and 5 of Table 12, 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 in general have better information on the technical expertise of other European firms and therefore exporting to that region brings little additional benefit. 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).

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, whereas when the firm exports to multiple regions it is more likely to choose person-to-person contact only. 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).

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 as the omitted 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).

Table 12: 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

Section 5: Conclusions

[to be completed]

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 suggest:

- Existing data can take us only so far on the question of international knowledge transfer. The split into exporting\non-exporting is too simplistic and cannot account for the geographic origin of information or allow for multiple channels for transfer.
- We can 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.
- We find value in extending the current literature and identifying where firms export to, the destination of exports is important.
- We find value in extending the current literature and including information on the origin of technical information used in R&D and for allowing the transmission of knowledge from multiple origins and channels (person-to-person contact, FDI and imports).
- Overall we conclude that there is evidence of a difference in behaviour in international knowledge transfer for innovation between exporters and non-exporters, but this relationship is not a simple positive one. Exporting to one region can make it more or less likely will source information from a different region or channel than non-exporters.
- We might 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. We find evidence of both, depending upon the channel and origin considered.

As Keller writes “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).

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[to be completed]

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