R&D and Exporting:
A Comparison of British and Irish firms

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Abstract
This paper investigates the two-way relationship between R&D and export activity. In particular, we concern ourselves with the question whether R&D stimulates exports and, perhaps more importantly, whether export activity leads to increasing innovative activity in terms of R&D (learning by exporting). We use two unique firm level databases for Great Britain and the Republic of Ireland and compare the results for these two countries. We find that previous exporting experience enhances the innovative capability of Irish firms. Conversely, no strong learning-by-exporting effects are found for British firms. Arguably part of the differences between Ireland and Britain are attributable to different, cross-country exporting patterns where Irish firms have a greater interface with OECD markets.

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1 Introduction

Theory and existing empirical work tells us that superior R&D capability leads firms to export. The argument goes that the prospect of coming head to head with foreign competition preselects only the fittest of firms: firms who have already 'raised their game' on the domestic market. In other words, the most innovative domestic firms, those with differentiated products and using cutting edge technology become exporters (Grossman and Helpman, 1995; Bleaney and Wakelin, 2002).

A less explored aspect of R&D and exporting is to what extent exporters learn from foreign competition in export markets and as a result improve their domestic innovation activity. Clearly exporters compete on export markets, become aware of and invest in foreign technologies and respond to the diverse needs of sophisticated foreign customers. In this case, exporters assimilate a foreign technology and upgrade their 'knowledge base' at home. The conjectured effect of exporting on innovation is therefore positive. However, while ample empirical evidence exists supporting a link from innovation to exports, the evidence so far for a causal effect of exporting on innovation in micro level data is weak, with the exception of recent studies by Aw et al., (2007) and Salomon and Shaver (2005) using data for Taiwan and Spain, respectively.

In this paper, we investigate the possible two-way relationship between exporting and innovation. Specifically, using firm level data for two countries we explore whether R&D activity stimulates exports and whether exporters demonstrate learning effects from their exporting activity through improving R&D activity post exporting. Similar to Aw et al. (2007) we recognize the interdependence of exporting and R&D by modelling the decisions to export and to invest in R&D simultaneously in a bivariate probit framework.

This is the first analysis to look these relationships within a simultaneous framework using data for developed economies.[1]

A further contribution of our paper is that we investigate this issue separately using unique firm level data for two countries, and we draw comparisons between the results. Specifically, we look at the Republic of Ireland and Great Britain. For Britain we link the BERD database at the ONS with the standard published data from Companies House obtainable through FAME. BERD contains among other things information on R&D expenditures. For Ireland we use data from the Annual Business Survey available from the State agency, Forfás. The country dimension highlights an important difference: while we find that exporting stimulates R&D activity in the case of Irish firms, there is no strong evidence for direct learning-by-exporting effects for British exporters.[2]

In brief, the possible explanations for differences between the Irish and British results are several. Firstly, there are issues of differing country size and domestic market, forcing Irish firms to export at an earlier stage of their development when they have most to learn. Secondly, the destination of output produced in each country is important. Irish firms export a greater proportion of their output to more advanced countries, a factor which may feed into enhanced innovativeness of Irish firms as a result of exporting.

We set up our paper in the following way. We first provide some background on the literature of R&D and exporting. We provide a brief description of our data before commenting on differences between Ireland and Britain in terms of exporting, R&D profiles, and the composition of our data. This is followed by the Methodology section

[1] Aw et al (2007) use a similar approach in their analysis of Taiwanese firm level data. However, they are unable to distinguish whether a firm invests in R&D or in training, while we focus particularly on R&D. Arguably, the decision to invest in R&D may be distinct from that of investing in training and, hence, it is important to distinguish those. Also, our data are a continuous annual panel, while Aw et al. have panel data separated by 5 year intervals.

[2] The British firm level data does not cover Northern Ireland (which is left out of the analysis). Hence, the data relates to Great Britain

and then our Analysis. Finally we conclude with a synopsis of our main findings and further discussion of our results.

2 Background on R&D and exporting

There is a well established theoretical literature describing the relationship between innovation and exporting. The main research questions address whether being innovative causes a firm to export, whether exporting makes a firm more innovative or whether the causal relationship runs in both directions. The strongest consensus in the theoretical literature is that exporting is often a by-product of innovative activity by domestic firms. In other words, there is general agreement in the literature that higher innovation rates spur exporting behaviour.

Effect of innovation on exporting

Specifically, the early theoretical literature posits a unidirectional relationship, running from innovation to exports (Vernon, 1966; Krugman, 1979). The intuition behind these early *product-cycle* models is that product differentiation and or innovation translates into competitive advantages that allow a firm to compete in international markets. A more recent generation of *neo-technology* models also supports this causal link (Greenhalgh, 1990; Greenhalgh and Taylor, 1994). More recently, Grossman and Helpman (1995) model the macroeconomic situation where firms improve the quality of their products (synonymous with innovation). The result is an outward shift in the country's export demand curve.

In tandem with the theoretical literature, there have been a number of studies showing how innovation fosters exports. Specifically in the case of UK and Ireland, studies showing the positive impact of innovation on exporting include Bleaney and Wakelin (2002), Wakelin

(1998) and Love and Roper (2001).[3] Bleaney and Wakelin (2002) find that firms are more likely to export if they are in a sector with a high R&D intensity (R&D to sales ratio). Wakelin (1998) uncovers a statistically significant positive correlation between innovation (measured in terms of number of innovations) and exporting. She interprets the positive relationship between innovation and exporting as suggestive of the role of innovation in supporting export growth. Love and Roper (2001) find that plants with in-house R&D capability are more likely to export.

Effect of exporting on innovation

There is a parallel theoretical literature which documents how we expect firms to learn from internationalisation i.e. among other things, the effect of exporting on innovation. The idea is that being exposed to a richer source of technology on export markets, could lead firms to improve their knowledge base. Hence a firm's export propensity can help it to raise its R&D capability and innovate. This literature investigates so called *learning by exporting effects.*[4] The concept of learning-by-exporting is consistent with theories of *endogenous innovation and growth* (Romer, 1990; Grossman and Helpman, 1991; Young, 1991). Specifically, Hobday (1995) develops a *technology-gap* model to illustrate how innovation rates are accelerated by foreign consumer demand and accordingly, a firm's exporting activities. He shows how knowledge is cumulative and its progression is mapped onto a firm's growth trajectory. The outcome of the model is that exporting pulls forward a firm's technology and accordingly innovative capacity.

As noted in the introduction empirical evidence for learning effects is weak (see Wagner, 2007). The convention when looking for learning effects is not to measure them directly but rather to use some proxy variable as a measure for learning. Examples of such proxies

[3] Work for other countries includes Lachenmaier and Wößmann (2006) and Wagner (2006) for Germany, Barrios et al (2003) using Spanish data and Sterlacchini (2001) using Italian data.
[4] Alternatively called learning by competing effects.

being a firm's productivity rate or average variable costs. Recent studies using a learning proxy include Baldwin and Gu (2003), Girma et al. (2004a). More recently, Salomon and Shaver (2005) have broken the mould by advancing the idea that using innovation as a proxy for learning provides a "more direct appraisal of the phenomenon". They add that firms should be able to improve their knowledge bases through their exporting activities. Specifically, exporting is a strategic action whereby a firm can improve its competitiveness.[5]

In line with the Salomon and Shaver (2005) assertion that a direct rather than indirect measure for innovation be used when appraising learning effects, Aw et al. (2005) use Taiwanese data to analyse a firm's decisions to export and invest in R&D and/or training. They apply a bivariate probit framework that recognises the interdependence of the exporting and R&D/training decisions. They find that exporting firms not investing in R&D or training have lower productivity rates than firms investing in R&D. They conclude that exporting firms, in particular, need to produce effective R&D or training in order to generate efficiency gains. Accordingly, they observe learning by exporting effects in Taiwanese firms. However, as pointed out in the introduction, one drawback of the study is that it does not distinguish between R&D and training expenditures.

Effect of exporter country and export market on export/ innovation relationship

Another strand of related literature informs us that the *degree of competitiveness* in foreign export markets is very important in driving domestic exporters to better performance (innovative or efficiency based performance). Arguably, firms that lie below the international technology frontier have the highest potential to benefit from technology transfers. However, this conclusion comes with the proviso that firms must possess

[5] Salomon and Shaver find that exporting is related to ex post increases in innovation using Spanish patent applications data.

sufficiently advanced internal R&D allowing them to absorb the knowledge. Specifically, in a macroeconomic study MacGarvie (2005) finds that domestic R&D capability is important and that knowledge is internalised more readily when countries share a common language or are technologically "proximate".

In a similar vein, Barrios et al. (2003) note that exporting spillovers are most likely to arise when Spanish firms trade with OECD member countries than non-OECD countries. In the former case the technology gap between the average Spanish exporter and competitor firms in the OECD markets was wider. Ruane and Sutherland (2005) furthermore argue that the nature of the foreign market is a key driver of learning-by-exporting effects. They distinguish between UK (local) and non-UK (global) markets for Irish exporters noting that the former represents less of a challenge to exporters and hence presenting less scope for learning effects.

3 Data Description

Our empirical analysis on the link between R&D and exporting is based on two unique firm level databases for Great Britain and Ireland. We collected data from a number of sources. The access to R&D data for Great Britain was not straightforward because the R&D data contained in the BERD database which is held at the UK Office for National Statistics needed first to be linked to published Companies House data (FAME) covering British firms in order to be able to link R&D to other firm characteristics.[6] FAME is a known published data source made available via Bureau van Dijk. The version of data that we use is FAME C. Fame C comprises a sample of UK firms having fixed assets, or current assets or current liabilities in excess of £150,000. As such it is a version of FAME

[6] BERD does not include firms from Northern Ireland, hence our UK sample effectively only relates to Great Britain and excludes Northern Ireland.

that widens the lens to consider such smaller and possibly younger firms at the periphery in addition to the standard selection of larger firms captured in less comprehensive versions of FAME.

The result was a unique dataset containing information on R&D expenditures for UK firms. As with many linking exercises, some information is lost. Coverage for the two databases overlapped only for the period 1996 to 2003, which is why our UK data is confined to this period. Overall the linked UK data covers about a third percent of all official R&D expenditures captured by Government.[7]

The micro-data that we use for the Republic of Ireland is collected by Forfás, the Irish policy and advisory board with responsibility for enterprise, trade, science, and technology and already contains information on R&D expenditures. Specifically, our data source is the *Annual Business Survey of Economic Impact (ABSEI)*, covering the period from 2000 until 2004. This is an annual survey of plants in Irish manufacturing with at least 10 employees, although a plant, once it is included, is generally still surveyed even if its employment level falls below the 10 employee cut-off point.[8] The survey was started in 2000 and the response rate is estimated by Forfás to be around 55 to 60 percent of the targeted population per year. This data set provides information on exports and R&D expenditure at the plant level, as well as other important firm characteristics.

Note that while the British data cover the period 1996 to 2003, the Irish data are only available from 2000 onwards. In order to maximise number of observations for the British sample, we use the full data for Britain and the 2000 to 2003 period for Ireland.

[7] For the period 2000 to 2002 the amount of R&D activity captured was 32.7%, 22.3% and 18.4% respectively.

[8] The Irish data is at the plant level, while the British data is at the firm level. This is not a problem for our analysis as most firms in Ireland are single plant firms (even among foreign multinationals).

Some useful statistics regarding the composition of the two samples used are given in Appendix 1. It is clear that British firms from the matched data are larger in terms of exports and sales than British firms in the full FAME database. This is a feature of matched data, where bigger firms, having more comprehensive accounts have correspondingly fewer missing observations and therefore a higher probability of matching with external data. The Irish data is unmatched because it already contained information on R&D expenditures. Irish firms are on average smaller than their British counterparts. However, Irish firms are significantly more export oriented than British firms, with exported output comprising over 75 percent and 33 percent for Irish and British firms respectively (Appendix 1).

4 R&D and exporting in Great Britain and Ireland

We start by looking at some aggregate statistics for our two variables of most interest: R&D intensity and export intensity for Ireland and Great Britain. We see from Table 1 that the rate of R&D expenditure was higher in Great Britain than in Ireland between 2000 and 2002. It should be pointed out that these pooled data may mask the peripheral role of R&D expenditure for foreign firms operating in Ireland as noted by Cassidy et al. (2005). The status of Ireland as an 'export platform' for such firms means that the R&D function is frequently derogated to elsewhere in the foreign MNE group: the result is comparatively low average commercial R&D for Ireland internationally.

[Table 1 near here]

Table 2 describes the breakdown of exports from Ireland and Great Britain by destination country. For the Irish data, a comparatively higher proportion of exports in the high-technology sector finds its way to OECD countries. In 2000, over 50 percent of exports in the high-technology sector found their way to OECD countries. For Great Britain, the

corresponding figure was just over 37 percent. For Great Britain, a comparatively high proportion of exports from the medium/ high technology sector is destined for OECD countries, with over 35 percent of exports in this category in 2000 going to OECD countries. The corresponding value for Irish firms in this category was 31 percent. If the destination of exports is indeed important for spillovers (Barrios et al, 2003) or to raise the efficiency of domestic exporting firms when faced with more dissimilar markets (Ruane and Sutherland, 2005), it follows that we may expect some dissimilarity in the impact of exporting for these two countries on their R&D and innovation profile i.e. differences in learning-by-exporting effects.

[Table 2 near here]

We now leave the aggregate data and turn to the specific data in our panels for the two economies. Table 3 shows that within the British sample, approximately 12 percent are foreign non-exporters, 31 percent foreign exporters, 13 percent are domestic non-exporters with a final 45 percent of the sample comprising domestic exporters.

[Table 3 near here]

Table 4 shows the weighting of exports accounted for by foreign firms in both countries. In Ireland, foreign firms are especially active in the export sector, accounting for 78 percent of total output but 89 percent of exports. In Britain there is greater equivalence between the export and turnover shares of foreign firms. Foreign firms account for roughly the same amount of exports and output as domestic British firms.

[Table 4 near here]

We can also examine the question 'How does being a domestic or foreign firm affect a firm's export intensity?' another way in Table 5. Here we look more closely at ownership/ exporting associations in the data. We see that foreign exporters in Britain exported on average 41.8 percent of their sales in 2000 compared with 80.8 percent for

foreign exporters in Ireland. Similar to Table 4, this highlights the dominance of foreign firms in exports in the Irish case compared to Britain. The same higher pattern for Irish foreign firms is repeated in 2001 and 2002. Domestic exporters in both economies appear to export a similar percentage of their sales, approximately 40 percent. The most telling fact about Tables 4 and 5 is that they show clearly the export platform status of Ireland: foreign firms use Ireland as an export base whereby they export the lion's share of production.[9]

[Table 5 near here]

Table 6 decomposes the two panels by research status. Our British sample shows a comparatively higher showing of R&D active foreign firms. This is in line with expectations and earlier comments, where foreign multinationals operating out of Ireland carry out the R&D activity elsewhere in the group (Love and Roper, 2001). We have a sizeable set of R&D non-active firms in our Irish sample compared to that for Britain (31.2 percent vs. 15.5 percent).

[Table 6 near here]

We move from the raw breakdowns of R&D in our samples to our first stab at analysing the association between R&D and foreign ownership in Table 7. What stands out is the comparatively high R&D intensities for Irish domestic exporting firms compared to their British counterparts. In 2000, for instance, Irish domestic exporters' R&D spend made up 16.7 percent of their total sales compared to an overall spend of 3.2 percent for British firms. This pattern was repeated for successive years. What seems clear across both countries is the heavier involvement of domestic exporters in R&D than domestic non-exporters. This may well be the result of underlying sectoral variation in the data where

[9] This pattern is also evidenced by Love and Roper (2001).

traditionally high-technology industries such as Pharmaceuticals with high export propensities are also R&D intensive.

[Table 7 near here]

We look finally at the breakdown of our data by exporting and R&D status in Table 8. The bulk of our firms in both panels are R&D active exporters, representing 54.6 percent and 48.8 percent of all firms in the British and Irish samples respectively.

[Table 8 near here]

5 Methodology

We have demonstrated in the motivation to our paper how R&D has been shown to be one of the main determinants of the export decision. Analogously, firms can expect to improve their R&D capability through the process of exporting (learning-by-exporting effects). Similar to Aw et al (2005) we formulate the export and R&D decision interdependently as a bivariate probit. More specifically, we estimate the probability of a firm being an exporter in time *t* as a function of a number of firm characteristics, the definition of which variables is contained in Appendix 2:

$$Prob(Exp_t = 1) =$$

$$f(\text{lagged export status, lagged R\&D status, lagged firm characteristics}) \quad (1)$$

Similarly, the probability that a firm undertakes R&D in time *t* is modelled as

$$Prob(R\&D_t = 1) =$$

$$f(\text{lagged R\&D status, lagged export status, lagged firm characteristics}) \quad (2)$$

The dependent variable in equation (1) is a dummy variable equal to one if the firm is an exporter in the current year, zero if not. The explanatory variables in this equation are chosen based on the related literature on the determinants of exports (e.g., Bernard and Jensen, 2004; Girma et al., 2004a). Following this literature, we include the lagged export status, i.e., a dummy variable equal to one if the firm was an exporter in year *t-1* in order to account for the importance of sunk costs. We also include lagged R&D status because in this framework the relationship between R&D and export status is central to our research question (e.g., Barrios et al., 2003).

Other firm characteristics in equation 1 are lagged productivity, lagged average wages, and lagged employment. We now describe the rationale for including this set of covariates.

Lagged productivity as a measure of firm efficiency is in line with existing work and accounts for the self selection of more efficient firms into exporting (Bernard and Jensen, 2004; Aw et al., 2007). Lagged average wage is included as a proxy for employee skill intensity, again in line with existing work (Bleaney and Wakelin, 2002; Bernard and Jensen, 2004; Ruane and Sutherland, 2005).[10] Employment size features in existing work as a covariate in estimating exporting and/or R&D propensity (Love and Roper, 2001; Lachenmaier and Wößmann, 2006; Barrios et al., 2003; Ruane and Sutherland, 2005).

Equation 2 models the determinants of firms' probability of undertaking R&D. The dependent variable is a dummy equal to one if it has any positive R&D expenditure in *t*, zero if not. The explanatory variables include a dummy indicating the R&D status of the firm in the previous period (equal to one if R&D active in *t-1*) in order to allow for

[10] The intuition for using average wage as a skills proxy rests on Mincer's (1974) human capital earnings function which shows a regression relationship between earnings, education and experience based on human capital theory. Willis (1999) provides a good review of this literature showing the positive role of human capital in determining wage rates.

persistence in the R&D decisions of firms. Other firm characteristics included are the same as in the export decision equation, as these are arguably all important in the R&D decision as well.[11] Also, to test for the importance of previous export activity causing new R&D expenditure (i.e., learning-by-exporting) we include a dummy equal to one if a firm was an exporter in the previous period *t-1*.

In this set up, it is likely that the error terms of the two equations are correlated, not least since the dependent variable in each equation is among the right hand side variables in the other equation. In order to take account of this relationship – the variables are jointly determined – the model needs to be estimated simultaneously. We do this using a bivariate probit estimation technique, which estimates a two equation probit model using maximum likelihood techniques (see e.g. Greene (2000) for a description).

6 Results

We set up our results in the following way. First we estimate the simultaneous effect of the R&D decision on the export decision, for domestic and foreign firms respectively, in Ireland and Britain. This is to check for any possible learning by exporting effects. In so doing, we carry out the analysis for domestic and foreign owned firms separately. The argument goes that it is domestic, rather than foreign firms who stand to benefit from exporting as the latter are already globally engaged players. [12] Accordingly, foreign firms are not expected to learn much that is new from exporting. This is a reasonable assumption to make given the recent insights into the causes and consequences of firm level heterogeneity (e.g., Helpman et al., 2004; Girma et al., 2004a) and the possibility

[11] See, for example, Hall (2002) for an overview of determinants of firms' R&D activities.

[12] Of course there should be more convergence between domestic multinationals and foreign firms given that both these types are global players. Strictly speaking, learning by exporting should be most pronounced for domestic exporters with no FDI. Unfortunately we do not have data on domestic multinationals

that foreign multinationals use certain host countries as export platforms – this is particularly an issue in the case of Ireland (Barry and Bradley, 1997).

We then check the robustness of our findings by including an FDI penetration variable to ensure that what we observe is a learning-by-exporting effect rather than a demonstration effect. A demonstration effect would arise if domestic firms in sectors with high FDI, observe what these foreign firms do and thereby improve their efficiency[13]. Finally, we check the robustness of the R&D/ export decision framework by checking whether our results also hold when the decision to conduct R&D or export respectively is expressed as R&D and export intensity.

Table 9 reports our estimations for domestic firms in Britain and Ireland. We do not see any significant impact of lagged productivity on either a firm's exporting or R&D status. What is very interesting is the differential effect of the lagged R&D and exporting status variables on current R&D and exporting status. For both Britain and Ireland, lagged exporting status is significantly related to exporting status (persistence of exporting). There is a general expectation that exporting is a persistent activity. Once a firm exports, it is more likely to do so in subsequent years. Similarly, lagged R&D status is significantly related to R&D status (persistence of R&D). However, only in the case of Ireland is lagged exporting status significantly related to R&D status. Columns 2 and 4 in Table 9 (Panel A) also show that the demonstration effect of FDI are important for the export decision of Irish firms although this is not the case for the British sample.

Let us examine the effect of lagged exporting status more carefully for Irish firms in Panel B. From columns 3 and 4, we see that the size and significance levels of the lagged export status coefficient suggest large and significant learning-by-exporting effects for Irish domestic exporters. The coefficient sign for lagged export status (columns 1 and 2),

[13] Calculated as R&D expenditure by foreign firms in 2-digit SIC industry as percentage of total output in the 2-digit industry. This is somewhat similar to the FDI productivity spillovers literature. See for example, Girma et al (2007) and Ruane and Ugur (2005) for the UK and Ireland respectively

although positive for British firms, is statistically insignificant. We can conclude that learning by exporting is experienced by Irish firms in our sample but not British firms. We now look at the effect of the other covariates on R&D status. There are cross-country differences in the role of size on the R&D decision. In Britain there are diminishing returns to size on the probability of undertaking R&D. In Ireland, firm size has a weakly positive effect on the R&D decision (columns 3 and 4).

Before moving on to summarise our findings for Table 9, we need to comment as to whether what we are witnessing is indeed a learning-by-exporting effect or rather a demonstration effect. Our regressions which include FDI penetration report our findings for learning-by-exporting, having netted out potential demonstration effects (as captured by our FDI penetration variable). We see that Irish firms still experience learning-by-exporting despite having controlled for demonstration effects. However, we should also note that the size of the coefficient on lagged exporting reduces once we net out sectoral FDI demonstration effects.

Taken together, these results suggest that there is persistence in innovative activity, but that there is no statistically significant evidence to suggest that there are direct 'learning-by-exporting' effects on R&D activity for British firms. Conversely, Irish firms exhibit 'learning-by-exporting' effects.

The nature of the non-linear simultaneous estimation technique implies that we cannot interpret the regression coefficients straightforwardly. In order to get an idea of the economic significance of the variables included in the model we can calculate the effect of a change in one of the lagged dummy variables on the joint probability that a firm exports and undertakes R&D.[14] We calculate marginal effects for our R&D and exporting dummy variables from our estimations in columns 2 and 4 of Table 9 for Britain and Ireland

[14] These marginal effects are calculated based on the coefficients and evaluating covariates at their mean. Greene (1996) derives the marginal effects for a conditional mean function in a bivariate probit model.

respectively. The marginal effects for the probit model describe the probability that a firm is both an exporter as well as conducts some R&D. It is therefore a joint probability. The marginal effect for our variable of interest, lagged export status shows the change in probability that a firm does both these activities when we look for differences between the group of exporters and non-exporters in the previous year. An Irish firm that exports in the previous year, has a 58 percent higher probability of both exporting as well as conducting R&D than one that does not export. The result for British firms in our sample is of the same magnitude but falls short of conventional statistical significance.

[Table 9 near here]

We would not expect to see positive or significant learning-by-exporting effects for foreign firms exporting out of either Britain or Ireland and this is borne out in results contained in Table 10. This is because MNEs by default are expected to have sourced their technology from abroad. They have little or nothing new to learn from the exporting experience. In order to pick up whether there are indeed any learning-by-exporting effects for foreign firms in our samples, we look at Panel B of Table 10 which focuses on the R&D decision. Looking specifically for a positive sign on the coefficient for lagged export status in order to discern learning-by-exporting effects, we fail to see any such effects for foreign MNEs in Ireland and Britain.[15] This result is in line with prior expectations i.e. learning-by-exporting effects are a feature of domestic industry and are not exhibited by foreign firms.

[Table 10 near here]

Up until now we have looked at R&D and export outcomes. In other words, we have observed in Table 9 and 10 how a firm which exported in the previous year now has a higher probability of conducting R&D in the current year. This exercise of looking at

[15] The coefficient in the British estimations is insignificant in column 3, where sectoral FDI penetration is considered. It is weakly negative in column 2.

lagged exporting status prompts the following question: would the *magnitude* of exporting the previous year have an impact on the magnitude of R&D conducted in the current year? In order to examine this closely related question we need to reformulate our outcome variables as export and R&D intensities and rerun our estimations using the 3-Stage Least Squares (3SLS) methodology. Table 11 reports our results for the 3SLS on the sample of domestic firms.

The results from the 3SLS are disappointing in so far as only the variables showing persistence in export and R&D intensity register any sizeable coefficients. However, we do pick up demonstration effects for both British and Irish firms as evidenced by the significant and positive effects of FDI penetration on R&D intensity of domestic firms. We do not, however, observe any significant learning-by-exporting effects. What we can conclude from a comparison of our findings regarding export status and the intensity of the exporting activity (Tables 9 and 11 respectively), is that any significant learning-by-exporting effects are picked up by exporting status. Being an exporter is what appears to matter for enhancing a firm's knowledge, not the extent to which a firm exports.

[Table 11 near here]

7 Conclusion

We find that previous exporting experience enhances the innovative capability of Irish firms through increasing R&D activity. In other words, Irish firms exhibit positive learning-by-exporting effects. Conversely, we do not find strong evidence for such direct effects of previous exporting on R&D for British firms.

There are some potential explanations for why our results differ for Ireland and Great Britain. To begin with, the economies are different in terms of the role of exporting. Great Britain represents a large economy with a lower share of exporters (relative to total

firms) than Ireland. We saw earlier how British firms have on average lower export shares (Appendix 1). Additionally we know from others that British exporters are 'better' firms i.e. there is self-selection (Girma et al., 2004a). Ireland represents a comparatively small and open economy. This is evidenced in the higher export shares of Irish firms. Evidence for self-selection of Irish exporters is mixed.[16] It is unclear how self-selection impacts on learning as its predicted effects are ambiguous. If exporters have strong ex-ante R&D capability (i.e. self-selection is strong), exporters possess good absorptive capacity and assimilate foreign technologies more easily. However, there is less need for them to do so. In the absence of self-selection, the average firm may be technologically less advanced than in the case of self-selection. However, domestic exporters farther from the technology frontier may have a greater need to learn from foreign firms. Hence, with self-selection, the *ability* to learn is stronger and in its absence the *need* to learn is stronger. Specifically, in the context of differences between learning-by-exporting effects for Irish and British firms, Irish firms may have to export earlier because there is less scope for them to supply the home market. Accordingly, Irish firms are exposed to international markets at an earlier stage in their knowledge function and are prompted to 'raise their game' at an earlier stage in their development. The fact that they are exposed to international markets so early, at a time when they have most to learn from the exporting experience, may induce such comparatively high learning-by-exporting effects.

Another potential reason for the significantly higher impact of exporting on Irish R&D capability is that a higher proportion of Irish high-technology sector exports go to OECD country markets (OECD, 2005). Irish firms might be forced to work harder at producing innovative outputs given the relative sophistication of such markets. We also see that Irish

[16] Ruane and Sutherland (2005) use a random effects methodology on a panel of Irish firms reveal self-selection of exporters. Furthermore, they find no evidence of learning-by-exporting effects. On the other hand, Girma et al (2004b) analysing ex ante productivity differentials on Irish data using a first order stochastic dominance methodology, find no significant differences in plant performance between domestic exporters and non-exporters.

domestic exporters in our sample have a comparatively higher R&D spend than their British counterparts, indicating that they have higher absorptive capacity to assimilate the knowledge that is being transferred from exporting.

Tables

Table 1: Average R&D expenditures

	Ireland	UK
2000	0.6%	2.2%
2001	0.6%	2.4%
2002	0.6%	2.5%

Calculated from aggregate BERD data for total manufacturing where values are R&D expenditures for the industry divided by output

Table 2: Destination of Exports

		Export shares to OECD countries (%)		
		High-technology	**Medium/high-technology**	**Low-technology**
Ireland	2000	50.2	31.0	15.9
	2001	58.2	23.8	15.0
	2002	57.9	27.5	12.0
UK	2000	37.4	35.3	14.4
	2001	40.3	33.2	13.9
	2002	38.5	34.8	14.5

Source: OECD (2005), OECD Science, Technology and Industry Scoreboard, OECD, Paris.

Table 3: Observations by nationality and export status

	Britain		Ireland	
foreign	**no. obs.**	**%**	**no. obs.**	**%**
non-exporter	847	11.9	147	1.5
exporter	2172	30.5	2559	26.1
domestic	**no. obs.**	**%**	**no. obs.**	**%**
non-exporter	911	12.8	1755	17.9
exporter	3190	44.8	5343	54.5

Notes:
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás

Table 4: % of exports and output by foreign firms

	Britain		Ireland	
% Exports	**no. obs.**	**%**	**no. obs.**	**%**
Foreign	2807	57	2709	89
Domestic	4314	43	7095	11
% Sales	**no. obs.**	**%**	**no. obs.**	**%**
Foreign	2807	53	2709	78
Domestic	4314	47	7095	22

Notes:
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás

Table 5: Average export intensity by nationality (in percent)

	Britain		Ireland	
	Domestic exporters	Foreign exporters	Domestic exporters	Foreign exporters
2000	42.1	41.8	37.7	80.8
2001	40.2	37.9	38.6	82.7
2002	37.1	33.9	39.5	82.5

Notes:
Calculated as total exports over total turnover by firm type
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás

Table 6: Observations by nationality and R&D status

	Britain		Ireland	
Non-R&D active	**no. obs.**	**%**	**no. obs.**	**%**
Foreign	805	11.3%	1363	13.9
Domestic	1104	15.5%	3059	31.2
R&D active	**no. obs.**	**%**	**no. obs.**	**%**
Foreign	2208	31.0%	1343	13.7
Domestic	2998	42.1%	4039	41.2

Notes:
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás.

Table 7: Average R&D intensity by nationality and export status (in percent)

	Britain			Ireland		
	Domestic exporter	Domestic non-exporter	Foreign exporters	Domestic exporter	Domestic non-exporter	Foreign exporters
2000	3.2	0.5	4.8	16.7	2.5	1.4
2001	1.9	1.1	4.4	12.0	9.8	6.5
2002	1.3	0.4	6.4	14.8	1.9	4.2

Notes:
R&D intensity calculated as total R&D expenditure over total turnover by firm type
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás.
Foreign non-exporters are omitted from this table as their numbers are too few in the Irish sample

Table 8: Observations by export and R&D status

	Britain		Ireland	
Non-R&D active	**no. obs.**	**%**	**no. obs.**	**%**
Non-exporter	442	6.2	1275	13.4
Exporter	1474	20.7	3137	31.8
R&D active	**no. obs.**	**%**	**no. obs.**	**%**
Non-exporter	1317	18.5	588	6.1
Exporter	3888	54.6	4804	48.8

Notes:
British data source: linked BERD / FAME data deposited at ONS
Irish data source: Annual Business Survey at Forfás.

Table 9: Results of bivariate probit regressions for domestic firms

Panel A: Export decision

	(1)	**(2)**	**(3)**	**(4)**
Lagged R&D status	0.189	0.226	0.392	0.415
	0.123	0.144	0.067***	0.067***
Lagged export status	3.602	3.480	3.075	3.081
	0.141***	0.171***	0.086***	0.082***
Lagged productivity	-0.007	0.023	-0.001	0.000
	0.069	0.087	0.001	0.000
Lagged wage rate	0.115	0.098	-0.002	-0.002
	0.041***	0.032***	0.001**	0.001**
Lagged employment	0.120	0.209	0.001	0.001
	0.050**	0.075***	0.001*	0.000*
FDI penetration in sector		0.851		30.321
		6.113		8.160***
Sector dummies	yes	no	yes	no

Panel B: R&D decision

	(1)	**(2)**	**(3)**	**(4)**
Lagged R&D status	0.902	0.957	0.392	2.714
	0.066***	0.075***	0.067***	0.060***
Lagged export status	0.041	0.143	3.075	0.273
	0.087	0.118	0.086***	0.067***
Lagged productivity	0.008	-0.007	-0.001	0.000
	0.052	0.068	0.001	0.000
Lagged wage rate	-0.001	0.005	-0.002	-0.000
	0.044	0.054	0.001**	0.000
Lagged employment	-0.059	-0.068	0.001	0.000
	0.025**	0.028***	0.001*	0.001*
FDI penetration in sector		-0.821		22.455
		3.41		6.277***
Sector dummies	yes	no	yes	no
Observations	2841	2238	5995	4308
Log pseudolikelihood	-1816.6	-1390.8	-2361.2	-1887.9
ρ	0.0116	0.358	12.95	11.3696
Prob $\rho = 0$	0.914	0.550	0.0000	0.0007

Source: linked BERD / FAME data deposited at ONS for Britain, ABSEI for Ireland
Regressions include full set of time and two digit industry dummies where stated
Regression coefficients and robust standard errors reported

Table 10: Results of bivariate probit regressions for foreign firms

Panel A: Export decision

	British sample		Irish sample	
	(1)	**(2)**	**(3)**	**(4)**
Lagged R&D status	0.253	0.480	0.246	0.270
	0.108**	0.143***	0.180	0.177
Lagged export status	3.681	3.661	3.891	3.758
	0.144***	0.194***	0.268***	0.222***
Lagged productivity	-0.032	0.193	0.000	0.000
	0.039	0.187	0.000	0.000
Lagged wage rate	0.263	0.343	-0.003	-0.005
	0.097***	0.171**	0.004	0.003
Lagged employment	0.034	0.097	0.001	0.000
	0.027	0.066	0.001	0.000
FDI intensity in sector		1.539		-23.142
		5.731		16.881
Sector dummies	yes	no	yes	no

Panel B: R&D decision

	(1)	**(2)**	**(3)**	**(4)**
Lagged R&D status	1.011	1.023	3.033	3.021
	0.076***	0.089***	0.112***	0.108***
Lagged export status	-0.145	-0.115	-0.089	-0.129
	0.082*	0.115	0.242	0.246
Lagged productivity	-0.036	-0.101	-0.001	-0.000
	0.033	0.064	0.001	0.000
Lagged wage rate	0.087	0.197	-0.001	-0.001
	0.051*	0.084**	0.003	0.003
Lagged employment	-0.088	-0.113	0.001	0.000
	0.027***	0.033***	0.001***	0.000***
FDI intensity in sector		2.134		9.015
		3.747		8.090
Sector dummies	yes	no	yes	no
Observations	2243	1631	1667	1677
Log pseudolikelihood	-2282.4	-1469.1	-471.4	-487.7
ρ	3.363	1.294	5.366	4.43164
Prob $\rho = 0$	0.0667	0.2552	0.021	0.0353

Source: linked BERD / FAME data deposited at ONS for Great Britain, ABSEI for Ireland
Regressions include full set of time and two digit industry dummies where stated
Regression coefficients and robust standard errors reported

Table 11: Results of 3-Stage Least Squares

Panel A: Export Intensity

	British sample		Irish sample	
	(1)	(2)	(3)	(4)
	Export Intensity	Export Intensity	Export Intensity	Export Intensity
Lagged export intensity	0.232	0.235	0.958	0.963
	0.025***	0.025***	0.004***	0.004***
Lagged R&D intensity	-0.025	-0.018	-0.001	-0.001
	0.037	0.037	0.001	0.001
Lagged productivity	-0.004	-0.005	0.000	0.00005
	0.003	0.003	0.000***	0.000**
Lagged wage rate	0.003	0.003	-0.000	-0.000
	0.003	0.003	0.000	0.000
Lagged employment	-0.001	-0.001	0.000	6.66e-06
	0.000	0.001	0.000	7.8e-06
FDI intensity in sector		-0.041		1.477
		0.157		0.316***
sector dummies	yes	no	yes	no
Constant	0.002	-0.041	0.015	0.006
	0.009	0.157	0.005***	0.004

Panel B: R&D intensity

	British sample		Irish sample	
	(1)	(2)	(3)	(4)
Lagged export intensity	-0.048	-0.046	0.019	0.031
	0.084	0.084	0.031	0.029
Lagged R&D intensity	0.034	0.043	0.366	0.368
	0.125	0.124	0.007***	0.006***
Lagged productivity	-0.016	-0.016	-0.000	-0.000
	0.011	0.011	0.000	0.000
Lagged wage rate	0.012	0.012	0.001	0.001
	0.011	0.011	0.001**	0.001**
Lagged employment	-0.002	-0.002	-0.000	-0.000
	0.003	0.003	0.000	0.000
FDI intensity in sector		1.170		5.826
		0.529**		2.248***
sector dummies	yes	no	yes	no
Constant	-0.010	1.170	-0.023	5.826
	0.029	0.529**	0.032	2.247***
Observations	2063	2063	4261	4251
Pseudo r^2 (expint)	0.07	0.06	0.93	0.93
Pseudo r^2 (rdint)	0.01	0.01	0.44	0.44

Source: linked BERD / FAME data deposited at ONS for Great Britain, ABSEI for Ireland
Regressions include full set of time and two digit industry dummies where stated
Regression coefficients and robust standard errors reported

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Appendix 1: Representativeness of the BERD/ONS/Fame data

British sample			
	Observations	Average turnover	Average overseas turnover
FAME data	709,269	£10.9 million	£1.3 million
Matched Fame/BERD data	10,361	£58 million	£19 million
Irish sample			
Observations	8,364	€4 million	€3.2 million

Sources: FAME data. Also ARD and BERD courtesy of the UK Office for National Statistics. Irish data courtesy of Forfás

Appendix 2: Variable definitions

export status	Dummy variable coded as 1 to denote exporters
export intensity	Firm level exports divided by firm level sales
employment	Number of full time employees
FDI intensity in sector	Calculated as R&D expenditure by foreign firms in 2-digit SIC industry as percentage of total output in the 2-digit industry
productivity	Output (sales) per worker
R&D status	Dummy variable coded as 1 to denote R&D active firm
R&D intensity	Firm level R&D divided by firm level sales
wage rate	Average firm level wage per worker