The University of Nottingham

research paper series

Globalisation, Productivity and Technology

Research Paper 2005/04

Knowledge accumulation and productivity: Evidence from plant level data for Ireland

by

Mark Cassidy, Holger Görg and Eric Strobl

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

GEP Leverhulme Centre for Research on Globalisation and Economic Policy

The Authors

Mark Cassidy is at the Central Bank and Financial Services Authority of Ireland. Holger Görg is a Lecturer in the School of Economics, University of Nottingham and an Internal Research Fellow in GEP. Eric Strobl is an Associate Professor at Université de Paris X – Nanterre.

Acknowledgements

This paper is prepared for a special issue of the *Scottish Journal of Political Economy* on "Economics of the Workplace". We are grateful to Forfás for the provision of the data. Financial support through the Leverhulme Trust (Grant No. F114/BF) is gratefully acknowledged. We would like to thank Richard Harris for helpful comments on an earlier version of the manuscript. All errors and omissions are our own.

Knowledge accumulation and productivity: Evidence from plant level data for Ireland

by

Mark Cassidy, Holger Görg and Eric Strobl

Abstract

This paper investigates whether knowledge accumulating activities, such as exporting, R&D, or worker training, can enhance plants' productivity. To this end we use plant level panel data for Irish manufacturing. Our results importantly indicate that productivity enhancing effects of these factors are found only for domestic firms, but not for foreign multinationals located in Ireland. We postulate a number of potential reasons inherent of multinational activity possibly driving this result.

JEL classification: L2, H2, F2, O3

Keywords: research and development (R&D), exporting, training, productivity, foreign ownership

Outline

Non-Technical Summary

The accumulation of knowledge has long been regarded as one of the key drivers of economic growth. Recently, the literature has focused on identifying these links in firm and plant level data in order to overcome the limitations inherent in the analysis of macro data. Our paper contributes to this literature by investigating the link between knowledge accumulation through R&D, training, and exporting and total factor productivity using plant level panel data for manufacturing industries in the Republic of Ireland. Arguably Ireland provides an especially interesting case study given its recent economic growth experience particularly in high tech sectors. Additionally, a prominent feature of Ireland's industrial structure is the importance of foreign multinational companies, accounting for roughly one half of manufacturing employment. Given the importance of inward FDI for the Irish economy, we make a point of investigating whether there are differences for domestic plants and affiliates of foreign-owned multinationals.

Our discussion suggest that training, exporting and R&D can potentially be productivity enhancing. However, in our data such relationships crucially depend on the nationality of ownership of the plant. Exporting is found to be associated with higher total factor productivity for both domestic and foreign-owned plants, though the result is stronger for foreign than for domestic firms. However, there is no evidence that engaging in R&D or training raises the productivity of foreign multinationals located in Ireland. In contrast, indigenous establishments reap productivity benefits if they engage in any of these knowledge enhancing activities, although there appear to be complex interactions between exporting and R&D, and exporting and training.

1 Introduction

The accumulation of knowledge has long been regarded as one of the key drivers of economic growth. On the theoretical side, traditional theory of economic growth, as developed by Solow (1956), indicates that technological change is responsible for long run economic growth. More recently, modern "endogenous" growth theory details the role of knowledge creation and shows how technology can drive sustained economic growth. In this literature, Romer (1990) stresses the importance of innovative activity and R&D, while Lucas (1988) focuses on knowledge creation through accumulation of human capital. Furthermore, Grossman and Helpman (1991) highlight the importance of trade as a conduit for improving the knowledge stock and, hence, growth in an economy. The importance of all these three channels of knowledge accumulation for growth has been substantiated in cross-country growth regressions (e.g., Coe and Helpman, 1995).

More recently, the attention has shifted to identifying these links in firm and plant level data in order to overcome the limitations inherent in the analysis of macro data. While country and industry level studies are necessary in order to establish empirical regularities, arguably the most useful information for policy makers is to be found at the firm or plant level. On the one hand, this is where policy can be aimed at and therefore it is necessary to understand the exact mechanisms at the micro level that drive the more aggregate results obtained at the industry or country level. This is important as there is substantial heterogeneity across firms even within narrowly defined industries which policy makers need to be aware of. From a more technical econometric point of view, this heterogeneity can lead to aggregation bias, as aggregate data are not able to account for the heterogeneity, which may lead to problems with the empirical results.

Our paper contributes to this literature by investigating the link between knowledge accumulation through R&D, training, and exporting and total factor productivity using plant level panel data for manufacturing industries in the Republic of Ireland. Arguably Ireland provides an especially interesting case study given its recent economic growth experience particularly in high tech sectors. Additionally, a prominent feature of Ireland's industrial structure is the importance of foreign multinational companies (MNCs), accounting for roughly one half of manufacturing employment. Given the importance of inward FDI for the Irish economy, we make a point of investigating whether there are differences for domestic plants and affiliates of foreign-owned multinationals.

Our paper is structured as follows. Section 2 provides a review of the firm/plant level evidence on the links between R&D, training, exporting and productivity. Section 3 provides some background information on R&D, training and exporting in the Irish economy, while Section 4 sets out the methodology and describes the data used in the empirical analysis. The econometric results are outlined in Section 5 and a summary and some concluding comments are contained in Section 6.

2 Literature review

In line with the macro studies mentioned in the introduction, knowledge accumulation at the level of the firm is usually measured in one of three forms: R&D, training or exporting. Of these, the literature on the firm level link between R&D and productivity is perhaps the most developed, dating back to the pioneering work by Mansfield (1965), Minasian (1969) and Griliches (1979). Since then, a large amount of research has been devoted to uncovering and quantifying this link for a large number of developed countries, much of it focussing on the US, France and Japan.[1] In some recent studies, Hall and Mairesse (1995) provide an extensive analysis of the relationship between R&D and productivity using firm level data for manufacturing firms in France over the period 1980 to 1987. They find a positive impact of firms' R&D activity on their productivity, with elasticities of output with respect to R&D capital of around 0.05 to 0.25, depending on the specification of the production function and the econometric technique employed.[2] Wang and Tsai (2003) examine data for Taiwan. They have access to panel data for 136 large firms over the period 1994 to 2000. Their approach is in the spirit of Hall and Mairesse (1995) in its estimation of a production function. They also find a positive productivity effect of R&D activity, with an output elasticity of around 0.18 – i.e., not too dissimilar from the study for France by Hall and Mairesse (1995).

While the Wang and Tsai (2003) study could be criticised for its small sample size and focus on large firms, Kwon and Inui (2003) provide a similar positive relationship for Japan using a much larger data set, covering around 3,800 Japanese firms in manufacturing, mining and commerce for the period 1995 to 1998. Nevertheless, their estimates appear somewhat lower than those obtained in previous research, with rates of return ranging between 0.02 and 0.14, depending on the specification and estimation method. Wakelin (2001) employs panel data for 170 quoted firms over the period 1988 to 1992 in the United

[1] This literature, which by and large finds a positive relationship between firms' R&D activity and productivity growth, is summarised in much detail by Mairesse and Sassenou (1991).

[2] These results are within the range of previous studies as reviewed by Mairesse and Sassenou (1991).

Kingdom. In her production function estimation she finds that the rate of return to R&D is 0.27, or "for every additional pound spent on R&D expenditure output would increase by £1.27 ceteris paribus" (p. 1084). However, once she controls for sector specific effects, no such link is apparent in the data.

There have also been a number of studies investigating the relationship between firm level training and productivity, although the beginnings of this literature only reach back to the early 1990s.[3] One of the earliest studies appears to be by Holzer et al. (1993) who use data for a sample of manufacturing firms in the state of Michigan. Analysing these firm level data they find that firm-sponsored training helps firms to reduce their scrap rate – i.e., improve their productivity. Bartel (1994) uses data for 1986 from the Columbia Business School survey covering more than 400 US enterprises to examine the relationship between labour productivity and employee training. In her analysis she finds that firms operating at less than their expected labour productivity in 1983 implemented training programmes which resulted in them achieving higher productivity growth between 1983 and 1986. Black and Lynch (1996) estimate an augmented Cobb-Douglas production function using data from the US National Employers' Survey for 1993, and again find that firms' investment in human capital in terms of training is positively related to productivity. In a follow up paper (Black and Lynch, 2001) they use panel data for 1987 to 1993 and find that different workplace practices, such as joint decision making or incentive based compensation, are positively related to productivity. However, their measure of training (measured in terms of number of workers trained in a firm) is not statistically significantly linked to productivity.

An even more recent literature has looked at the productivity benefits accruing to exporters compared to non-exporters. The argument here is that firms either self-select into exporting, i.e., high productivity firms choose to become exporters, or there is learning-by-exporting, where firms are exposed to international competition and hence are able to learn and improve their productivity performance. Evidence on the positive link between exporting and productivity has recently been provided for a number of countries. The pioneering studies in this field of research are Clerides et al. (1998), who provide a detailed study of the link between exporting and productivity for Colombia, and Bernard and Jensen

[3] Other papers have focused on the effects of training on the individual. For example, Bassi (1984) using data from the US Continuous Longitudinal Manpower Survey for 1977 and 1978 finds that women benefiting from training tend to earn higher wages, while no such effect is found for men. Booth (1991) undertakes a similar study with data from the British Social Attitudes Survey of 1987 and finds evidence that some forms of training tend to increase wages.

(1999) who provide the first of such studies for the United States. Their lead has been taken up in a number of papers investigating the exporting – productivity relationship using firm or plant level data for a number of countries, e.g., Girma, Greenaway and Kneller (2004) for the United Kingdom, Bernard and Wagner (2001) for Germany, and Delgado et al. (2002) for Spain.

While all of the above cited micro-studies each examine one of the channels for knowledge accumulation in isolation, Aw and Batra (1998) consider simultaneously the link between R&D, training, exporting and productivity at the firm level, using cross section data for Taiwanese manufacturing firms in 1986. They link firms' productivity to its R&D activity, training expenditure and exporting status with the rationale that all three activities reflect firms' endeavours to access and utilise new technology in order to improve performance and build up absorptive capacity to utilise new knowledge. From their data, they are not able to distinguish firms' R&D from their training activity, instead employing a dummy variable which indicates whether a firm engages in R&D and/or training. They find that this variable is positive and statistically significant in most of their regressions, indicating a positive link between R&D / training activity and firms' efficiency. Also they find that exporters are more efficient than non-exporters.

3. Knowledge Accumulation in Ireland: R&D, Training and Exporting

Strong productivity growth in the Irish economy during the 1990s was largely driven by the performance of foreign multinationals in a small number of knowledge-intensive, export-oriented, manufacturing sectors, including electrical and electronic equipment, medical instruments and chemicals and pharmaceuticals (Cassidy, 2004). As a result, the Irish economy now has the highest degree of specialisation in high-technology sectors, as classified by the OECD according to R&D intensity, in the European Union (ECB, 2004). It has been widely argued that this restructuring of Irish manufacturing was facilitated by a number of factors including the skills of the domestic labour force. This section provides some brief background information on the evolution of the Irish manufacturing sector in the context of the link between knowledge accumulation through exporting, R&D and training and total factor productivity.

Ireland is a very open economy, with a trade to GDP ratio of almost 70 percent in 2000 – one of the highest in the European Union (Ruane and Sutherland, 2002). Industrial policy in Ireland has, since the late 1950s, been oriented towards supporting export growth.

The opening up of the economy during the second half of the twentieth century was undertaken through a dual strategy of promoting the export orientation of the indigenous manufacturing sector and attracting foreign manufacturing companies to produce in Ireland for export markets. In particular, an attempt was made to encourage exports through fiscal incentives, most notably a very favourable corporation tax rate for exporting firms.

The expansion of the Irish exporting sector was primarily driven by FDI inflows. The contribution of (mainly US) multinational firms to Ireland's economic growth performance during the 1990s has been well documented (e.g. Barry and Bradley 1997, Görg and Strobl 2002, 2003a). The foreign sector of the Irish economy is characterised by extremely high export-orientation and productivity levels. In 2001, the latest year for which data are available, foreign owned firms in the Irish manufacturing sector exported around 93 per cent of their output, compared to a corresponding figure of 37 per cent for Irish owned firms. Labour productivity levels, measured as gross value added per worker were, in the same year, around five times higher in the foreign sector than in the indigenous sector of manufacturing.

The Irish economy's high degree of specialisation in the production of high technology output stands in stark contrast to the economy's low level of industrial R&D activity, a fact that has been noted by the OECD (1998). For example, total business expenditure on R&D (BERD) in 2001 was only 0.8 per cent of GDP which, in a European context, leaves the economy closer to the Mediterranean economies, which are in general characterised by low-technology output, than the Northern European economies which tend to have higher technological intensities and higher R&D expenditures. Aggregate data released by Forfás, the Irish policy and advisory board with responsibility for enterprise, trade, science, and technology in Ireland, show that the contrast is particularly acute for the foreign sector of the economy, which contributed substantially to the strong productivity performance of the Irish economy during the 1990s. The data released by Forfás show that R&D intensity of foreign-owned firms, not only in the aggregate manufacturing sector but also in the high-technology sub-sectors, is somewhat less than in indigenous firms and very low by international standards (see Table 1). However, it is also worth noting that the economy had a very low R&D base in 1980 and, subsequently, the rate of increase in the business sector R&D capital stock has been high by international standards, particularly during the 1990s.[4]

[4] See Guellec and van Pottelsberghe de la Potterie (2001).

[Table 1 here]

In addition to industrial policy, successive Irish governments have also been able to influence economic performance through investment in human capital. In practice this has generally taken the form of investment in formal education rather than support for enterprise training. The economy has also benefited, however, from the presence of foreign multinationals and the high skill levels of returning migrants during the 1990s. There exists a two-way relationship between FDI and human capital. A skilled labour force, capable of working with the technologies of knowledge intensive multinationals is required in order to attract foreign direct investment in the first place. The presence of foreign high-technology firms can then yield spillover effects on the domestic economy through employee training and technological advances.

The available data on the extent of staff training in Irish firms is rather limited and difficult to interpret. A recent OECD study shows that Ireland ranked quite low across selected OECD countries in terms of the participation of workers in job related education and training and also in hours per employed person in the same activities – however, for Ireland the data referred to 1994 (OECD 2003). A more recent indicator published in the WEF Global Competitiveness Report 2002-2003, based on a qualitative survey, showed that in 2003 the Irish economy ranked 9th out of 16 OECD countries in terms of the extent of staff training.

Domestic studies indicate that training activities appear to be reasonably widespread among Irish firms. In a sample of manufacturing plants with more than 10 employees Barry et al. (2004) find that over 70 percent of plants included in the sample provide training. The average training expenditure was around £250, a figure comparable to that for Australia found by Dumbrell (2002). The study finds that around 88 per cent of foreign firms provided training compared to only 68 per cent of domestic firms. However, this was largely a consequence of foreign firms being more concentrated in those sectors associated with higher training expenditures. When sectoral level training is controlled for, it is found that foreign plants are actually less likely than domestic plants to provide training. As would be expected, there is evidence that exporters and R&D active establishments spend more on training than other plants.

In terms of linking these knowledge accumulating facets to productivity, micro-level studies for the Republic of Ireland have been limited. For example, to the best of our knowledge, there have been no studies looking at the effect of own R&D activity on productivity at the firm level. The only related studies in terms of R&D and firm performance is that based on firm level R&D surveys by Kearns and Ruane (2001, 1998). Specifically, in Kearns and Ruane (2001) the authors examine the effect of R&D by foreign-owned plants on the duration over which that plant remains in Ireland and show that R&D indeed is an important positive determinant for survival of foreign-owned plants. Kearns and Ruane (1998) provide a similar analysis for domestic plants, again showing that R&D active plants have higher probabilities of survival than non-R&D active establishments. As regards training, Barrett and O'Connell (2001) employ survey data for a small sample of Irish manufacturing firms and find that general training increases productivity. This positive relationship does not hold for firm specific training, however. For the importance of exporting, Love and Roper (2001) investigate determinants of exporting using firm level data. Finally, Girma, Görg and Strobl (2004) use a non-parametric test on plant level data for manufacturing firms to investigate productivity differentials between domestic exporters, non-exporters and Irish-owned multinational firms. They find that, while the latter are more productive (in terms of labour productivity) than the former, exporters which are not multinationals do not appear to have a productivity advantage compared to non-exporters. Nevertheless, it becomes clear that currently there is no comprehensive study available that examines the link between R&D, exporting, training and productivity. This is what this paper sets out to do.

4. Methodology and data

In order to examine how investment in knowledge accumulation at the plant level influences total factor productivity we estimate a Cobb-Douglas production function in logs augmented by measures of knowledge creation,

$$y_{it} = \alpha k_{it} + \beta m_{it} + \lambda l_{it} + \kappa KA_{it} + \varepsilon_{it} \qquad (1)$$

where *KA* captures the different measures of knowledge creation at the plant level. We include logs of capital, materials and labour as inputs, represented by *k*, *m* and *l*, respectively. Other time invariant plant and industry specific effects (e.g., nationality of ownership, technology level and competition in the industry) are captured by a time invariant component of the error term, μ_i , where $\varepsilon_{it} = \mu_i + v_{it}$. As we discuss in more detail below, our data set only covers two years, hence we are reasonably confident that a fixed effect captures most industry determinants of productivity.

A potential problem with estimating this production function is that plants may observe TFP at least partly and that this may influence the choice of factor input combinations in the same period. Hence, there would be a correlation between the error term (ε_{it}) and the contemporaneous covariates, leading to biased estimates of the coefficients. This is usually referred to as a simultaneity problem. In order to deal with this problem we assume that the time invariant component of the error term (μ_i) is the part that is observed by the plant, while v_{it} is the remaining error term (assumed to be white noise) which includes unobserved shocks as well as measurement error. Our identifying assumption is that μ_i is a plant specific time invariant effect and the model can thus be estimated using a fixed effects (within transformation) estimator. Arguably, assuming the observed component to be a fixed effect is not a reasonable assumption in a long panel. However, our data set only covers two years and, hence, the assumption of a fixed effect appears viable.[5]

For the estimation of the empirical model we utilise information from the *Annual Business Survey* collected by Forfás. This is an annual survey of plants in Irish manufacturing from 1999 until 2002, covering plants with at least 10 employees, although a plant, once included, is generally still surveyed even if its employment level falls below the 10-employee cut-off point. The survey generally covers around 50 per cent of all manufacturing plants with 10 or more employees. In essence, our sample is therefore a random sample of plants with at least 10 employees. This should be kept in mind for the interpretation of the empirical results.

Importantly the data set provides information on total R&D expenditure, expenditure on training, and total value of exports at the plant level. Furthermore, it includes a time invariant indicator variable which allows us to identify foreign-owned firms. An important point to note is that Forfás defines foreign plants as plants that are majority-owned by foreign shareholders, i.e., where there is at least 50 per cent foreign ownership. While, arguably, plants with lower foreign ownership should still possibly be considered foreign owned, this is not necessarily a problem for the case of Ireland since almost all inward foreign direct investment has been greenfield investment rather than acquisition of local firms (see Barry and Bradley, 1997).

5 One potential problem with using the FE estimator is that it only uses the within plant variation in the data. This could imply that the coefficients may be only weakly identified. This should be kept in mind when interpreting the results below, which may hence be seen as lower limits of the true effects. Unfortunately, the use of only two years of data prevent us from implementing other more refined strategies to deal with the simultaneity

A further noteworthy point is that the data on R&D expenditure do not allow us to distinguish process from product innovation. Arguably, one may expect greater productivity effects from process innovation, which is directed at implementing new production techniques in the plant. On the other hand, product innovation, while being productivity enhancing through the introduction of new products, also encompasses product upgrading or adaptation which would not be expected to have large impacts on productivity.

Further data available from this source that is relevant to the current paper are total sales (as a measure or output), employment, total purchased materials and components, total fixed assets (in book values, as a measure of physical capital), and sector of production.[6] While the survey has been carried out for four years, questions on fixed assets were only included for two years, namely 2000 and 2001. Since we need this variable to construct measures of total factor productivity, the data we use for our empirical analysis relate only to those two years.

5. Econometric results

In order to examine the link between investment in knowledge and plant level productivity we estimate variants of equation (1) including indicator variables for plants engaging in R&D, training and/or exporting. The results of these estimations using data for all plants are reported in column 1 of Table 2. The first point to note is that the dummy indicting whether or not a plant is an exporter is positive and statistically significant, indicating that exporters are more productive than non-exporters. This finding is in line with the large international evidence on productivity premia associated with exporting (e.g., Clerides, Lach and Tybout, 1998; Bernard and Jensen, 1999). More specifically, the point estimate suggests that exporters' TFP is 2.5 percent higher than that of non-exporters.

We also find that plants investing in training reap productivity benefits. Based on the point estimate we find that plants engaged in training have a TFP advantage of 0.3 percent, ceteris paribus. However, there does not appear to be any statistically significant productivity enhancing effect of the incidence of R&D.

---

problem, such as the approaches by Olley and Pakes (1996), Levinsohn and Petrin (2003) or a GMM approach with lagged values as instruments.

[6] All nominal variables are deflated by the consumer price index, as no plant or sector level deflators were available to us.

This result on R&D could perhaps be due to the large presence of foreign multinationals in the sample. Since it is usually postulated that multinationals carry out most or all of their "headquarter services", including R&D and training in the home country (e.g., Markusen, 2002), we investigate whether there are differences for domestic plants and affiliates of foreign-owned multinationals. To this end, we report in the next two columns results of estimations for domestic and foreign-owned plants separately. We find for both nationality groups that exporting is positively associated with higher total factor productivity, though this result is stronger for foreign than for domestic plants. The striking result, however, is that we only find a statistically significant positive relationship between investment in training and productivity for domestic Irish-owned plants, while there is no such evidence for foreign-owned plants. Also, for both types of plants there is no evidence for positive productivity effects of R&D.

The results for foreign plants may reflect the nature of R&D and training undertaken in foreign plants, as these are by definition affiliates of foreign multinationals. For example, as multinationals are usually expected to undertake most of their R&D and training activity in the home country at headquarters, R&D activities in the foreign affiliates may hence be limited to product upgrading rather than process innovation. However, expenditure designated for product upgrading may only have little impact on productivity, as most of the productivity enhancement would be expected from process innovation. Unfortunately, as pointed out above, we do not have data to distinguish product from process innovation. Training may also be only directed towards marginal improvements in human capital, rather than to substantial knowledge creation as in domestic plants. Moreover, training in foreign multinationals may constitute more informal training.

[Table 2 here]

One should note that our findings of no statistical relationship between R&D activity and productivity for foreign-owned plants lie in contrast to the findings by Kearns and Ruane (2001). They, using data for 1980 to 1996, find that R&D active foreign plants in Ireland have higher probabilities of survival than non-R&D active foreign plants. While it is difficult to compare the two studies, we can make a few general points. First, plant survival is usually postulated to depend on profitability rather than productivity (see Audretsch, 1995) and one would not necessarily expect a perfect positive correlation between these two indicators of plant performance. Related to this, Kearns and Ruane

(2001) may only be picking up the fact that non-R&D active foreign plants are more footloose than R&D active plants, as they may be more closely bound into the international production network (see Görg and Strobl, 2003b). Second, the time periods analysed in the two papers are different, with Kearns and Ruane (2001) covering the 1980s to mid 1990s, while we examine 2000-2001. Third, Kearns and Ruane (2001) do not include other plant level covariates, apart from plant size, in their empirical hazard model.

Turning back to the results for domestic plants in column (2), the coefficients suggest that the productivity advantage for being an exporter and undertaking training equals 0.31 + 1.45 = 1.76. These two coefficients are, of course, estimated ceteris paribus and do not allow for any interactive effects. In order to allow for such, we report in columns (4) to (6) estimations including interaction terms for R&D and exporting as well as training and exporting.[7] Examining the effects of R&D, the estimates for domestic firms in column (5) show that R&D activity for non-exporting plants is associated with a reduction in TFP by 1.23 percent compared to non-R&D active non-exporters. The productivity benefit of being an exporter and being R&D active is equal to –1.23 + 1.94 + 1.59 = 2.30 percent compared to a non-R&D active non-exporter. A non-R&D active exporter also has an advantage over non-R&D active non-exporters of 1.94 percent. As regards training, being an exporter engaged in training is associated with a productivity benefit of 1.74 + 1.94 – 1.95 = 1.75 compared to a non-training active non-exporter.

The results thus far only consider the incidence of investment in knowledge and exporting. For the latter, this approach is justified by the idea that exporting involves sunk costs and plants that can overcome this entry barrier have an advantage over other firms (e.g., Meltiz, 2003). In this case, how much is exported is immaterial. For the former, however, there is no such theoretical underpinning. Hence, there is no reason to suspect that different levels of investment may not bestow different productivity advantages to plants. In order to investigate this, we estimate equation (1) including the log of R&D and training expenditure per employee as independent variables instead of the dummies.

The results are reported in Table 3. Examining the coefficients for domestic plants in column (2) shows that an increase in training expenditure per employee by 1 percent is associated with a TFP increase by 0.05 percent, while a comparable increase in R&D expenditure is associated with a reduction in productivity by 0.06 percent. One possibility for this negative effect is perhaps that benefits for R&D are only reaped in the long term for

[7] Note that due to collinearity we can now no longer estimate the exporting and R&D dummies separately for foreign plants.

some plants. For example, for less productive plants with less access to skilled labour and machinery, like non-exporters, initial R&D activity may involve the allocation of skilled labour and technology intensive capital away from normal production, leading to lower productivity. In other words, while there may be long-term benefits to conducting R&D, in the short run production may not be at its optimal level. One reason for this may be that less productive plants are more financially constrained and find it more difficult to find outside funding for R&D and hence must reallocate resources internally. Unfortunately our short time series and the lack of other information in our data do not allow us to investigate this possibility any further.

The results for foreign-owned plants are, again, not statistically significant.[8] Again including interaction terms between the export dummy and the expenditure variables shows for domestic plants that the productivity advantage through R&D only accrues to domestic exporters but not non-exporters, while the opposite is true for training expenditure and exporting. For foreign-owned plants the inclusion of the interaction term does not lead to any significant changes.

[Table 3 here]

6. Conclusion

In this paper we examined whether there are productivity benefits to be derived from engaging in certain knowledge accumulation activities, namely R&D, training of workers and exporting of goods, in Irish manufacturing. Our results suggest that all three of these can be productivity enhancing. However, such relationships crucially depend on the nationality of ownership of the plant. Exporting is found to be associated with higher total factor productivity for both domestic and foreign-owned plants, though the result is stronger for foreign than for domestic firms. However, there is no evidence that engaging in R&D or training raises the productivity of foreign multinationals located in Ireland. In contrast, indigenous establishments reap productivity benefits if they engage in any of these knowledge enhancing activities, although there appear to be complex interactions between exporting and R&D, and exporting and training.

The strikingly different results for foreign plants are perhaps not surprising. They reflect the fact that the increased internationalisation of production and the surge in foreign direct investment over the past thirty years has served to complicate the relationship between knowledge accumulation *at the plant level* and total factor productivity. Globally, multinational firms still tend to undertake most of their key R&D and training activity in the home country and this would appear to be very much the case for foreign affiliates based in Ireland. As a result, technological transfers from parents to affiliates based in Ireland are a further significant means of enhancing the stock of knowledge in foreign owned firms – perhaps more important than R&D and training propensities of the affiliate. However, while R&D and training expenditures of foreign owned plants in Ireland might not have a direct impact on the firm's productivity, the domestic economy can potentially benefit from these activities through the creation of jobs for highly skilled staff and positive spillover effects (see Figini and Görg, 1999, Görg and Strobl, 2002, 2003a).

Moreover, an economy's ability to absorb imported technology, and also its ability to benefit from the spillover effects of the R&D and training activities of multinationals in the domestic economy, is likely to be enhanced by the R&D activity and quality of human capital of indigenous firms, which would imply an additional channel through which domestic knowledge accumulation can affect productivity. Unfortunately the nature of our data did not allow us to investigate these issues relating to technology transfers, spillovers and knowledge accumulation further, although they clearly deserve further attention.

[8] Note that the sample size has reduced compared to Table 2 due to the data requirements. This means that in this estimation we no longer have any foreign plants that switch between exporting and non-exporting, hence, we cannot estimate the coefficient on the export dummy.

Table 1: R&D expenditure as a % of gross output in Irish and foreign owned manufacturing firms (2001)

Sector	**Irish owned**	**Foreign owned**	**OECD average**
Electrical & Electronic equipment	4.2	1.2	5.6
Pharmaceuticals	2.3	1.2	11.5
Instruments	1.8	1.2	7.0
Food, Drink and Tobacco	0.3	0.2	0.3
Machinery and Equipment	1.8	1.0	2.1
Chemicals	0.4	0.1	3.2
Rubber & Plastics	1.2	0.5	1.2
Non metallic minerals	0.6	1.4	0.8
Basic & Fabricated Metals	0.6	0.3	0.7
Wood & Wood products	1.0	1.4	0.2
Transport Equipment	0.7	0.4	4.5
Textiles / Clothing	0.7	0.7	0.3
Other manufacturing	0.3	0.2	1.0
Paper, Print and Publishing	0.2	0.0	0.4
Total Manufacturing	**0.8**	**0.6**	**2.4**

Source: Forfás "Business Expenditure on Research and Development" (2001)

Table 2: Investment in knowledge and total factor productivity

	(1)	(2)	(3)	(4)	(5)	(6)
	All	Domestic	Foreign	All	Domestic	Foreign
RD dummy	-0.055	-0.010	-0.059	-0.020	-1.232	-0.059
	(0.139)	(0.164)	(0.209)	(0.276)	(0.271)***	(0.209)

Training dummy	0.332	0.310	0.049	1.314	1.741	-8.320
	(0.125)***	(0.130)**	(0.303)	(0.232)***	(0.220)***	(0.499)***
Export dummy	2.448	1.446	8.370	3.454	1.942	
	(0.179)***	(0.187)***	(0.403)***	(0.290)***	(0.290)***	
RD * Export				-0.057	1.593	
				(0.286)	(0.293)***	
Training * Export				-1.288	-1.956	8.370
				(0.256)***	(0.248)***	(0.403)***
capital	0.387	0.477	0.170	0.360	0.441	0.170
	(0.032)***	(0.036)***	(0.056)***	(0.032)***	(0.035)***	(0.056)***
labour	0.599	0.595	0.300	0.575	0.639	0.300
	(0.116)***	(0.132)***	(0.190)	(0.116)***	(0.127)***	(0.190)
materials	0.059	0.029	0.054	0.060	0.049	0.054
	(0.019)***	(0.024)	(0.027)**	(0.019)***	(0.023)**	(0.027)**
Constant	0.855	1.197	-1.257	0.405	0.792	7.096
	(0.438)*	(0.437)***	(0.976)	(0.443)	(0.425)*	(0.944)***
Observations	2753	1760	993	2753	1760	993
Number of plants	1383	884	499	1383	884	499
R-squared	0.30	0.35	0.50	0.32	0.41	0.50

Notes:

Fixed effects estimation

Standard errors in parentheses

* statistically significant at 10%; ** at 5%; *** at 1%

Table 3: R&D and training in levels

	(1)	(2)	(3)	(4)	(5)	(6)
	All	Domestic	Foreign	All	Domestic	Foreign
RD expenditure	0.168	-0.063	0.092	-0.558	-0.523	-0.051
	(0.063)***	(0.030)**	(0.060)	(0.111)***	(0.131)***	(0.630)
Training expenditure	0.018	0.046	-0.016	0.248	0.248	-0.079
	(0.015)	(0.012)***	(0.036)	(0.033)***	(0.037)***	(0.563)
Export dummy	2.161	1.257		0.654	0.647	
	(0.230)***	(0.133)***		(0.258)**	(0.287)**	
RD * Export				0.771	0.788	0.148
				(0.103)***	(0.116)***	(0.634)
Training * Export				-0.270	-0.269	0.065
				(0.034)***	(0.038)***	(0.564)
capital	0.008	0.131	0.123	0.016	0.010	0.121
	(0.049)	(0.031)***	(0.161)	(0.046)	(0.052)	(0.162)
labour	0.467	0.926	0.233	0.387	0.353	0.247
	(0.153)***	(0.056)***	(0.184)	(0.143)***	(0.183)*	(0.187)
materials	-0.001	0.086	0.157	0.002	-0.030	0.157
	(0.025)	(0.011)***	(0.034)***	(0.023)	(0.028)	(0.034)***
Constant	4.706	2.390	6.599	6.307	6.266	6.542

	(0.707)***	(0.205)***	(1.329)***	(0.676)***	(0.786)***	(1.340)***
Observations	1540	1107	433	1540	1107	433
Number of plants	826		234	826	592	234
R-squared	0.13	0.57	0.14	0.25	0.27	0.15

Notes:

Fixed effects estimation

Standard errors in parentheses

* statistically significant at 10%; ** at 5%; *** at 1%

References

Audretsch, D.B. (1995), *Innovation and Industry Evolution*, Cambridge, M.A.: MIT Press.

Aw, B.Y. and G. Batra (1998), Technological capability and firm efficiency in Taiwan (China), *World Bank Economic Review,* 12, 59-79.

Barrett, A. and P.J. O'Connell (2001), Does training generally work? The returns to in-company training, *Industrial and Labor Relations Review,* 54, pp. 647-662.

Barry, F. and J. Bradley (1997), FDI and trade: The Irish host-country experience, *Economic Journal,* 107, pp. 1798-1811.

Barry, F., H. Görg and E. Strobl (2004), Multinationals and training: Some evidence from Irish manufacturing industries, *Scottish Journal of Political Economy,* 51, pp. 49-61.

Bartel, A.P. (1994), Productivity gains from the implementation of employee training programs, *Industrial Relations,* 33, pp. 411-25

Bassi, L.J. (1984), Estimating the effect of training programs with non-random selection, *Review of Economics and Statistics,* 66, pp. 36-43.

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

Bernard, A.B. J. Wagner (1997), Exports and success in German manufacturing, *Review of World Economics / Weltwirtschaftliches Archiv,* 133, pp. 134–57.

Black, S.E. and L.M. Lynch (1996), Human-capital investments and productivity, *American Economic Review Papers and Proceedings,* 86, pp. 263-267.

Black, S.E. and L.M. Lynch (2001), How to compete: The impact of workplace practices and information technology on productivity, *Review of Economics and Statistics,* 83, pp. 434-445.

Booth, A.L. (1991), Job-related formal training: who receives it and what is it worth?, *Oxford Bulletin of Economics and Statistics,* 53, pp. 281-294.

Cassidy, M. (2004), Productivity in Ireland: Trends and Issues, *Central Bank of Ireland Quarterly Bulletin*, Spring, pp.83-106.

Clerides, S., S. Lach and J. Tybout (1998), Is learning by exporting important? Micro-dynamic evidence from Columbia, Mexico and Morocco, *Quarterly Journal of Economics,* 113, 903-948.

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

Delgado, M. A., J.C. Farinas and S. Ruano (2001), Firm productivity and export markets: A non-parametric approach, *Journal of International Economics,* 57, 397-422.

Dumbrell, T. (2002), Industry differences in expenditure training, UTS Research Centre for Vocational Education and Training Working Paper 02-06.

ECB (2004), Sectoral Specialisation in the EU: A Macroeconomic Perspective, *Occasional Paper Series*, No.19.

Figini, P. and H. Görg (1999), Multinational companies and wage inequality in the host country: The case of Ireland, *Weltwirtschaftliches Archiv*, 135, pp. 594-612

Girma, S., H. Görg and E. Strobl (2004), Exports, international investment, and plant performance: Evidence from a non-parametric test, *Economics Letters,* 83, pp. 317-324.

Girma, S., D. Greenaway and R. Kneller (2004), Entry to export markets and productivity: A microeconometric analysis of matched firms, *Review of International Economics*, 12, pp.855-866.

Görg, H. and E. Strobl (2002), Multinational companies and indigenous development: An empirical analysis, *European Economic Review,* 46, pp. 1305-1322.

Görg, H. and E. Strobl (2003a), Multinational companies, technology spillovers, and plant survival, *Scandinavian Journal of Economics,* 105, 581-595.

Görg, H. and E. Strobl (2003b), 'Footloose' multinationals?, *The Manchester School,* 71, 1-19.

Griliches, Z. (1979), Issues in assessing the contribution of R&D to productivity growth, *Bell Journal of Economics,* 10, 92-116.

Grossman, G.M. and E. Helpman (1991), *Innovation and growth in the global economy*, Cambridge, MA: MIT Press.

Guellec, D and B. van Pottelsberghe de la Potterie (2001), R&D Productivity Growth: Panel Data Analysis of 16 OECD Countries, OECD STI Working Papers No.2001/3.

Hall, B.H. and J. Mairesse (1995), Exploring the relationship between R&D and productivity in French manufacturing firms, *Journal of Econometrics,* 65, pp. 263-293.

Holzer, H.J., R.N. Block, M. Cheatham and J.H. Knott (1993), Are training subsidies for firms effective? The Michigan experience, *Industrial and Labor Relations Review,* 46, pp. 625-636.

Kearns, A. and F. Ruane (1998), The post-entry performance of Irish plants: Does a plant's technological activity matter?, Trinity Economic Papers 98/20, Trinity College Dublin.

Kearns, A. and F. Ruane (2001), The tangible contribution of R&D spending foreign-owned plants to a host region: a plant level study of the Irish manufacturing sector, *Research Policy,* 30, 227-244.

Known, H.U. and T. Inui (2003), R&D and productivity growth in Japanese manufacturing firms, Discussion Paper 44, Economic and Social Research Institute, Tokyo.

Levinsohn, J. and A. Petrin (2003), Estimating production functions using inputs to control for observables, *Review of Economic Studies,* 70, pp. 317-341.

Love, J. and S. Roper (2001), The determinants of export performance: Panel data evidence for Irish manufacturing plants, NIERC WP69, Queen's University Belfast.

Lucas, R.E, Jr. (1988), On the mechanics of economic development, *Journal of Monetary Economics,* 22, pp. 3-42.

Mairesse, J. and M. Sassenou (1991), R&D and productivity: A survey of econometric studies at the firm level, *Science Technology Industry Review*, No. 8, 9-43 (OECD, Paris),

Mansfield, E. (1965), Rates of return from industrial research and development, *American Economic Review,* 55, 310-322.

Markusen J.R. (2002), *Multinational firms and the theory of international trade*, Cambridge, M.A.: MIT Press.

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

Minasian, J. (1969), Research and development, production functions and rates of return, *American Economic Review,* 59, 80-85.

OECD (1998), *Internationalisation of Industrial R&D: Patterns and Trends*, Paris: OECD.

OECD (2003), *Employment Outlook 2003*, Paris: OECD.

Olley, S. and A. Pakes (1996), The dynamics of productivity in the telecommunications equipment industry, *Econometrica,* 64, pp. 1263-1297.

Pretschker, U. (1998), "Introduction: The OECD's Mission in the Field of Public Support to Industry", *STI Review*, 21. pp. 13-24.

Raut, L.K. (1995), R&D spillover and productivity growth: Evidence from Indian private firms, *Journal of Development Economics,* 48, pp. 1-23.

Romer, P. (1990), Endogenous technical change, *Journal of Political Economy,* 98, S71-S102.

Ruane, F. and J. Sutherland (2002), Globalization, europeanization and trade in the 1990s: Export responses of foreign and indigenous manufacturing companies, in: H. Kierzkowski, ed., *Europe and Globalization,* London: Palgrave, pp. 207-228.

Solow, R.M. (1956), A contribution to the theory of economic growth, *Quarterly Journal of Economics,* 70, 65-94.

Wakelin, K. (2001), Productivity growth and R&D expenditure in UK manufacturing firms, *Research Policy,* 30, pp.

Wang, J. and K. Tsai (2003), Productivity growth and R&D expenditure in Taiwan's manufacturing firms, NBER Working Paper 9724.