ESRI

Working Paper No. 406

September 2011

Internationalisation and the Innovation Activities of Services Firms[1]

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Abstract: This paper examines the relationship between the internationalisation of firms in services and their innovation performance. We use firm-level data over the period 2004-2006 and estimate an augmented structural model to account for the role of foreign direct investment and exporting on the innovation performance of services firms in Ireland. Our research shows that in comparison to firms serving only the Irish market, domestic exporters were more likely to engage in R&D and innovation and they were more likely to be successful in terms of innovation output, over and above firm characteristics such as size and distance to the technology frontier. Further, we find that adoption of information and communication technologies was positively associated with innovation output. Co-operation with suppliers was positively associated with all innovation types, while knowledge flows from customers and from the government or public research institutes were positively linked to product innovation. Co-operation with universities was positively linked to innovation measured by patents.

Key words: Multinational Firms, Exporting, Knowledge Production, Services

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[1] This research uses statistical data from Forfás and the Central Statistical Office (CSO) of Ireland. The permission for controlled access to confidential micro data sets has been granted in line with the Statistics Act, 1993. The use of these statistical data does not imply the endorsement of Forfás or the CSO in relation to the analysis or interpretation of the statistical data. We thank Frances Ruane and participants at the international conference SEVICEGAP in Dublin and the European Trade Study Group Congress in Copenhagen for useful comments and suggestions. This paper is part of a project funded by the European Commission under the 7th Framework Programme, Grant Agreement No. 244522.

Internationalisation and the Innovation Activities of Services Firms

1. Introduction

The New-New Trade Theory has established that firms with international linkages are more productive than firms serving only the domestic markets. A large empirical literature has found that exporters are more productive than non-exporters and they often have higher productivity growth[2]. This productivity advantage of exporters could be explained by two hypotheses (Bernard and Jensen, 1999; Bernard and Wagner, 1997: (i) more productive firms self-select into export markets; (ii) learning-by-exporting. The theoretical model by Melitz (2003) has shown that only firms with a productivity level above a critical threshold find it profitable to export. This self-selection of more productive firms into export markets can be explained by the presence of fixed and variable costs associated with exporting. Exporting could make firms more productive through two channels: first, export starters could improve their post-entry performance due to knowledge flows from international buyers; second, international competition puts pressure on exporters to improve their productivity faster than firms selling only on domestic markets. Helpman et al. (2004) show that in the presence of fixed costs to exporting and to undertaking foreign direct investment, multinationals are the most productive firms in their country of origin, followed by domestic exporters.

While this literature has assumed that firm productivity is exogeneous, more recent theoretical contributions allow for the possibility of firms to increase their productivity through innovation activities (Yeaple, 2005; Bustos, 2011). A positive correlation between exporting and innovation activity has been found in several studies (Wagner, 1996; Roper and Love, 2002). In addition, a number of recent empirical studies have found that exporters are more likely to introduce product innovation (Liu and Buck, 2007; Salomon and Shaver, 2005; Fafchampsa et al, 2008; Bratti and Felice, 2010). Furthermore, additional recent empirical evidence suggests that foreign-owned firms and exporters are more likely to innovate (Criscuolo et al, 2010; Siedschlag et al, 2010).

Most of these studies focus on manufacturing firms. In contrast, Siedschlag et al (2010) examined the effects of internationalisation of firms on their innovation and productivity performance in manufacturing and in services firms in Ireland. They found both similarities and differences with respect to the effects of international linkages on innovation and productivity for manufacturing and services firms. Notably, while foreign-owned firms in manufacturing were more likely to invest in innovation and to be successful at innovating, they find no significant link in the case of foreign-owned firms in services.

This paper extends our previous research on the relationship between the internationalisation of firms and innovation. Specifically, we analyse the relationship

[2] Wagner (2007) and Martins and Yang (2009) surveyed recent empirical studies

between the internationalisation of services firms and their innovation performance by using a richer data set in comparison to Siedschlag et al. (2010). We ask the following research questions: Are services firms with international linkages more likely to invest in innovation and do they innovate more than firms serving only the domestic market?

Given the growing importance of services in the economies of developed countries and the increasing internationalisation of services, understanding the role of international linkages on the innovation performance of firms is relevant and important for both research and policy making. Services account for a growing share of economic activity in developed economies and they are the main engine of employment growth (OECD, 2004). With growing tradability of services and increasing exposure to competition, there is more pressure for services firms to innovate and increase productivity. Existing empirical evidence (van Ark et al., 2008) suggests that the productivity gap between the European Union and the United States is mainly due to the contribution of market services to the aggregate productivity.

The analysis of services and of innovation in services needs to account for a number of distinct characteristics of services in comparison to manufacturing such as intangibility, heterogeneity, simultaneity and perishability (Johne and Storey, 1998; Miles, 2005). The intangible nature of services makes measurement of output in services activities more difficult. At the same time, it makes imitation easier than in manufacturing. Services activities are heterogeneous in terms of technology and skills intensities which makes standardisation more difficult. Another distinct characteristic of services is that production and consumption take place simultaneously. Finally, services cannot be held in stock which implies that the responsiveness of services to demand needs to be higher. While innovation rates in services are lower than in manufacturing, innovation rates in service industries such as computer activities are higher than in manufacturing. Innovation in services is predominately non-technological and it is less related to R&D. Services are users of new technologies such as information and communication technologies (ICT), they are more dependent on human capital in comparison to manufacturing and closer to consumer demand. However, given increased linkages and growing similarities, boundaries between manufacturing and services are becoming less clear, (Howells, 2001).

Given existing differences and similarities between services and manufacturing, the analysis of innovation in services has evolved in three schools of thought (Tether, 2003). Up to the 1980s, manufacturing and only a few services, specifically, computer services and telecommunications, have been seen as the principal source of new technologies and the engine of growth. As a consequence there has been little attention paid to services before the 1980s. The traditional school (Pavitt, 1984; Pavitt et al, 1989; Barras, 1986, 1990) has looked at services as being to a large extent dependent on technology and innovation developed externally. In this traditional view, services were classified as supplier-dominated industries, passive adopters of externally developed technologies, mainly in manufacturing. Subsequent research in this tradition has acknowledged that some services can be sources of new technologies. The approach taken in this school of thought to the analysis of innovation in services is to apply to services the models developed to understand innovation in manufacturing.

The traditional school has been challenged by a group of researchers associated with University of Lille in France (Gallouj and Weinstein, 1997; Sundbo and Gallouj, 2000). In this view, innovation in services is different in comparison to innovation in manufacturing, in particular given intangibility and interactive aspects. Innovation in services is developed jointly especially with service users and there is a strong emphasis on interactions and co-operations for innovation.

Finally, a third emerging view of innovation draws on the Austrian and evolutionary economics and the competence based theory of the firm (Tether et al, 2001; Howells, 2000). In this view, different innovation paths are possible within each sector, namely manufacturing and services.

In this paper we use an integrated analytical framework to analyse innovation in services. Namely, while we start from models of innovation in manufacturing, we account for both similarities and differences in comparison to the innovation behaviour of firms in manufacturing. In particular, we model the roles of skills and the use of new technologies such as the information and communication technologies (ICT) on the innovation activities of firms. We use two linked firm level data sets from Ireland, namely the Community Innovation Survey (CIS) and the Annual Services Inquiry (ASI) over the period 2004-2006.

The remainder of this paper is organised as follows. Section 2 discusses the analytical framework and econometric methodology. Next, we present our data and summary statistics. Section 4 discusses our empirical results and Section 5 concludes.

2. Analytical Framework and Econometric Model

Our empirical analysis draws on the econometric framework proposed by Crépon et al (1998) to analyse the link between innovation inputs and innovation outputs at firm level. This modelling framework accounts for the following firm behaviour: in the first stage, firms decide whether and how much to invest in innovation; next, firms produce knowledge (innovation outputs) using innovation inputs and other inputs. Thus, the model consists of three equations which explain: (i) the propensity of firms to invest in innovation; (ii) the intensity of their innovation investment; (iii) the relationship between innovation investment intensity and innovation output.

To estimate these relationships we need to account for two econometric issues, namely selection bias and simultaneity. Selection bias is an issue because not all firms engage or report innovation investment. As pointed out by Griffith et al (2006), firms may not report innovation expenditure below a certain threshold. In addition, simultaneity may arise because there might be unobserved firm characteristics which have an impact on both innovation inputs and innovation outputs.

We estimate the first two equations as a generalized Tobit model using Heckman's two-step estimation procedure. The two-step Heckman procedure corrects for possible sample selection in the innovation input equation.

The firms' innovation effort is modelled by the following equation:

$$r^* = z_i\beta + \varepsilon_i$$

r^* is a latent variable, z_i is a vector of determinants of the innovation effort, β is a vector of parameters and ε_i is the error term. The firm's innovation effort is measured by their innovation expenditure denoted by r. $r = r^*$ only if firms make (and/or report) such expenditures. The latent variable is unobserved for all other firms. To proxy the propensity of firms to invest in innovation we estimate the following selection equation:

$$rd = \begin{cases} 1 \;\; if \;\; rd^* = x_i\gamma + u_i > \tau \\ 0 \;\; if \;\; rd^* = x_i\gamma + u_i \leq \tau \end{cases}$$

The observed binary variable, *rd* equals one for innovation-active firms and zero for the rest of the firms. The corresponding latent variable is rd^*. Firms engage in innovation and/or report innovation expenditure if rd^* is above a certain threshold level τ. z_i is a vector of variables explaining the innovation decision, γ is the parameter vector and u_i is the error term.

Because r^* is only observed when rd^* is larger than the threshold value, the following assumptions must be made about their joint distribution for the model to be estimable:

$$(u_i, \varepsilon_i) \sim \text{iid N}(0, 0, \sigma_u^2, \sigma_\varepsilon^2, \rho_{u\varepsilon})$$

That is to satisfy the condition that both error terms are normally distributed with mean zero, variances as indicated and correlation coefficient $\rho_{\tau u}$. The error terms are assumed to be independent of both sets of explanatory variables. As a simplifying assumption of the error term in the selection equation is normalised to 1, $\text{var}(u) = \sigma_u^2 = 1$. Given these assumptions r^* and rd^* can be considered jointly normal random variables and so the properties of the bivariate normal distribution can be used in estimating the model.

The dependent variable in the selection equation is a binary variable which is equal to one for firms which report innovation expenditure and zero for the rest of the firms. We use two measures for innovation expenditure, namely in-house R&D expenditure and total innovation expenditure. We model the propensity to invest in innovation as a function of international linkages, firm size, absorptive capacity as well as unobserved industry fixed effects. With respect to international linkages, we use dummy variables to distinguish foreign owned firms and domestic exporters. The omitted group consists of firms serving only the domestic market, domestic non-exporters. We use employment to proxy firm size and the distance to the global technology frontier to measure absorptive capacity[3].

The expected value of the observed innovation expenditure intensity r is conditional on the firm engaging in innovation and the values of z and is given by the following equation:

$$E\left(r_i \mid rd_i = 1, z_i\right) = \beta z_i + \left(\varepsilon_i \mid u_i > -x_i\gamma\right)$$

The right hand side is composed of the expected value of the underlying latent variable r^* plus an error term that results from selection bias. As u_i is restricted to be above a certain value, it is bounded from below. Firms not meeting this value are excluded.

Using the properties of the bivariate normal distribution, the above equation can be written as:

$$E\left(r_i \mid rd_i = 1, z_i\right) = \beta z_i + \rho_{\varepsilon u}\sigma_\varepsilon\lambda_i\left(-x_i\gamma\right)$$, where

$$\lambda_i\left(-x_i\gamma\right) = \frac{\phi\left(-z_i\gamma\right)}{1-\Phi\left(-z_i\gamma\right)}$$

The second term is the inverse mills ratio or selectivity regressor. To estimate the parameters for the underlying latent variable βz_i, the second term is treated as an omitted variable and estimated. This selectivity regressor is estimated for each firm. The parameter on this variable indicates the propensity of firms to have unobserved characteristics on whether to innovate or not. Adding this variable as a regressor in the model will pull the sample and the population mean to be the same value. The consistent estimates of β from the Heckman procedure are used to calculate the predicted values of innovation expenditure intensity.

The dependent variable in the innovation expenditure intensity equation is innovation expenditure per employee. The explanatory variables are international linkages, the firms's absorptive capacity and unobserved industry fixed effects.

The last equation of the model is the following innovation production function:

$$g_i = r_i^*\alpha + h_i\delta + e_i$$

where g_i is innovation output proxied by product, process, and organisational innovation indicators. The predicted values of innovation intensity r^* from the selection model enter as an explanatory variable in this model. These values are predicted for all firms not just the sample reporting innovation expenditure. By using the predicted values of this variable to instrument the innovation effort r^*, we account for the possibility that innovation

[3] The distance to the global technology frontier is computed as the difference between the productivity of the top global firms (the 90th percentile) by industry and firm productivity .

expenditure intensity is endogenous in the innovation production function. The selection and innovation effort equations thus correct for endogeneity. h_i is a vector of other determinants of innovation output, α and δ are the parameter vectors and e_i is the error term.

The dependent variable in the innovation output equation is a binary variable equal to one if the firm reported innovation output. We use four measures for innovation output: product, process, organisational innovation and patent applications. The potential limitation of the patents-based measure of innovation can be seen in that many more firms in all categories report the other innovation measures. As mentioned in Criscuolo et al. (2010) this indicates that the measures in the Community Innovation Survey pick up a greater variety of innovation types and so provide a greater depth of information on firm's activity which is not picked up in patent-based innovation measures which capture only frontier patentable innovations. The patent-based innovation measure does however allow the results to be compared with the previous literature on firm's innovative performance which predominantly use patents as the dependent variable.

The explanatory variables include the predicted innovation expenditure intensity, international linkages, firm size, wages per employee (a proxy for skills), the distance to the global technology frontier (a proxy for absorptive capacity), ICT usage, external knowledge flows from co-operation for innovation and unobserved industry fixed effects. We proxy ICT usage by two variables: a binary variable which equals one if the firm has a web-site and zero otherwise (an extensive margin of ICT adoption); the percentage of sales from e-commerce (an intensive margin of ICT adoption). To measure external knowledge flows we use binary variables which are equal to one if the firm reported the following distinct co-operations for innovation: with other enterprises within the same enterprise group; with suppliers of equipment, materials, components or software; with clients or customers; competitors or other enterprises in the same sector; with consultants, commercial labs or private R&D institutes; with universities or other higher education institutions; with government or public research institutes.

Detailed definitions and data sources of all variables are given in Appendix A1.

3. Data and Summary Statistics

The data used in this paper consists of two merged data sets provided by the Central Statistical Office of Ireland: the Community Innovation Survey (CIS) 2004 – 2006 and the Annual Services Inquiry (ASI) 2006.

The ASI is designed to provide grossed estimates of the principal trading aggregates for all enterprises in the relevant sectors. The sample is drawn from the Central Statistics Offices' Central Business Register (CBR) with the statistical unit used for the survey being the enterprise; this is defined as the smallest legally independent unit. The sample is stratified by employment size class, NUTS 2 region and NACE Rev1.1 code. A census of enterprises with 20 or more persons is taken with a stratified random sample selected for smaller enterprises. The CBR is used to gross the sample data to population estimates. Two different grossing factors are used, one for the number of enterprises and one for the accounting and employment variables. The grossing variable data in the responding sample are used to update the corresponding variables on the register.

The CIS uses the same statistical unit as the AIS, the enterprise. The CIS sampled enterprises with 10 or more persons engaged in the NACE Rev1.1 divisions 51 to 72 and NACE groups 74.2 and 74.3. A census of all enterprises with 50 or more persons engaged was taken. For enterprises with 10 to 49 persons engaged a stratified random sample was taken. As in the ASI the CBR is used to gross the data to population estimates.

Our benchmark sample consists of 532 firms which are surveyed in the CIS 2004-2006 and in the ASI 2006. This number represents 26.95% of the total number of responses to the CIS survey in 2006. The distribution of firms by industry can be seen in Table 1. As shown in Table 1, NACE 51, wholesale trade and commission trade, excluding motor vehicle and motor cycles is the largest single category accounting for 44.4% of firms. The second largest category is other businesses activity with 12.4%.

[Table 1 here]

Table 2 shows summary statistics for the firms in our sample grouped in five categories: all firms, foreign-owned (131 firms, 24.6% of all firms), exporters (203 firms, 38,2% of all firms), domestic firms (401 firms, 75.4% of all firms), domestic exporters (148 firms, 27.8% of all firms).

Foreign-owned firms and exporters have a similar innovation performance (innovation rates equal to 70%). Foreign-owned firms and domestic exporters are more innovative than domestic firms. This pattern is found for all innovation measures.

[Table 3 here]

Table 3 shows the mean values for innovation inputs and innovation drivers. Foreign firms spend the most on innovation and on in-house research and development. The mean value of expenditure on innovation is €10,977 for foreign firms compared to €5,946 for domestic firms. Global engagement is again important as exporting firms had above average expenditure on innovation and R&D as do domestic exporters when compared to domestic firms. Although foreign firms had higher levels of expenditure on innovation, they had the lowest mean engagement and the second lowest engagement in in-house R&D. The engagement in innovation expenditure for all firms was 27%.

In terms of the other variables, domestic firms had the lowest mean values for size, e-sales, presence of a website and wages per employee. Foreign-owned firms had the highest figure for all of these variables aside from e-sales which are higher for exporters. Foreign-owned firms are also the closest to the global technology frontier. The summary statistics show that foreign-owned firms and exporters use more innovation inputs and innovation drivers than domestic firms. This fact may be reflected in the innovation output performance differentials reported in Table 2. There is a large difference between domestic and domestic exporters in terms of e-sales.

[Table 3 here]

Table 4 shows mean values for the co-operation for innovation variables. Foreign- owned firms and domestic exporters had the highest co-operation rates. Foreign-owned firms however had the highest co-operation rates for co-operation with other enterprises within the same enterprise group and the lowest for co-operation with consultants. Exporters, domestic firms and domestic exporters had the highest co-operation rates for co-operation with suppliers and the lowest for co-operation with government or public research institutes.

[Table 4 here]

4. Empirical Results

The estimates of the parameters of the econometric models described above are shown in Tables 5, 6 and 7. Similar to other studies of this type a caveat must be mentioned in relation to the results presented as the estimations are done using cross-sectional data only. Following the counterfactual approach of defining causality (Finkel, 1995), with cross-section data the true causal effect can only be observed if a unit homogeneity assumption holds. In our analysis, this would only hold if it was possible to observe all relevant factors for all firms in the sample so there would be no unobserved heterogeneity. It would then be possible to accurately estimate the effect of each variable. The caveat is therefore that it is possible that there is unobserved heterogeneity due to unobserved variables and so an endogeneity problem. In this case, estimates could not be interpreted as accurate causal effects but as correlations only.

[Table 5 here]

The first part of Table 5 shows the estimates of the propensity to invest in innovation. The second part of Table 5 shows the estimates for the intensity of innovation expenditure conditional on investing in innovation. The first column shows the estimates when the dependent variable is engagement in R&D and R&D expenditure intensity, respectively. Specifically, the dependent variable is a binary variable equal to one if the firm reported in-house R&D expenditure and the level of in-house R&D expenditure per employee, respectively. The second column shows the propensity and intensity results obtained with innovation expenditure as the dependent variables. The estimates in Table 5 are obtained with a two-step Heckman estimator. The numbers shown are marginal effects and standard errors reported in parentheses are clustered at industry level. All specifications include two-digit industry dummies to control for possible cross-firm heterogeneity arising from industry effects.

Larger firms and domestic exporters are more likely to engage in R&D and in innovation, more broadly. Domestic exporters had a higher propensity of investing in in-house R&D and in innovation by 130 and 57 percentage points respectively when compared with the omitted reference group, domestic non-exporters. These results are in line with the literature (Crépon et al, 1998). Domestic exporters had a higher intensity of in-house R&D and innovation expenditure in comparison to firms that served only the Irish market. These results are line with Damijan (2008) and Griffith et al (2006). More productive firms had a higher R&D and innovation expenditure intensity in comparison to domestic non-exporters. On average, productivity lower by one percent in comparison to the global technology frontier decreases the probability of investing in in-house R&D and innovation by .02 and .05 percent respectively.

Tables 6 and 7 show the results of the innovation output equations. Again all numbers in the tables are marginal effects and standard errors reported in parentheses are clustered at industry level. All specifications also include two-digit industry dummies. All variables aside from size, predicted R&D intensity, log of wages per employee, distance to the frontier and e-sales turnover are binary variables. The predicted values are the predicted values of R&D intensity in Table 6 and innovation intensity in Table 7 for all firms using the fitted values of the Heckman sample selection model. Four different dependent variables are used: "Product Innovation", "Process Innovation", "Organisational Innovation" and "Patents". All dependant variables are binary variables equal to one if the firm reported an innovation of a given type or a patent application.

[Table 6 here]

Table 6 shows the innovation output equations with the fitted values of in-house R&D expenditure used to construct the innovation input variable. The marginal effects of R&D expenditure intensity are positive and significant for organisational innovation. An one percent increase in the R&D expenditure intensity increases the probability of having an organisational innovation by 22.2 percentage points. Domestic exporters are more likely to have product and organisational innovation. Larger firms are more likely to innovate. The largest correlation is obtained for patent applications. This result is in line with the "first Schumpeter hypothesis" where large firms have an advantage in innovation performance (Martin 1994). Distance to the global technology frontier is positively and significantly associated with organisational innovation. Having a web-site increases the probability to have product and organisational innovation while e-sales are positively correlated with applications for patents. Higher skills proxied with wages per employee are positively associated with patent applications. Product innovation is positively and significantly associated with co-operations with other enterprises within the same group, with suppliers, with customers, and with government or public research institutes. The highest correlations are found for co-operations with government and with customers. Co-operation with consultants was negatively associated with product innovation. Process innovation was positively and significantly associated with co-operations with other enterprises within the same enterprise group and with suppliers. Organisational innovation was positively associated with co-operation with suppliers while patent applications was positively associated with co-operation with universities.

[Table 7]

Table 7 shows the innovation output equations with the fitted values of total innovation expenditure used to construct the innovation input variable. The estimates are broadly qualitatively similar with those obtained using in-house R&D expenditure as a measure of innovation effort. In this case, we find no significant correlation between innovation expenditure intensity and innovation output. Domestic exporters were more likely to have product and process innovation.

5. Conclusions

This paper examined the relationship between the internationalisation of firms in services and their innovation performance. We use firm-level data over the period 2004-2006 and estimate an augmented structural model to account for the role of foreign direct investment and exporting on the innovation performance of services firms in Ireland.

Our research shows that in comparison to firms serving only the Irish market, domestic exporters were more likely to engage in R&D and innovation and they were more likely to be successful in terms of innovation output, over and above firm characteristics such as size and distance to the technology frontier. Further, we find that adoption of information and communication technologies was positively associated with innovation output. Co-operation with suppliers was positively associated with all innovation types, while knowledge flows from customers and from the government or public research institutes were positively linked to product innovation. Co-operation with universities was positively linked to innovation measured by patents.

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Table 1: Distribution of Firms by Industry

NACE Industry Description		2006	
	NACE Code	Number	Percent
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50	4	0.75
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	236	44.36
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	52	7	1.32
Land transport; transport via pipelines	60	37	6.95
Water transport	61	7	1.32
Air transport	62	5	0.94
Supporting and auxiliary transport activities; activities of travel agencies	63	44	8.27
Post and telecommunications	64	15	2.82
Financial intermediation, except insurance and pension funding	65	3	0.56
Activities auxiliary to financial intermediation	67	45	8.46
Computer and related activities	72	61	11.47
Research and development	73	2	0.38
Other business activities	74	66	12.41
Other service activities	93	0	0.00
Sum		532	100

Notes: The cells indicate the number of firms from each service industry NACE category present in the data set and the percent of the sample accounted for by firms from each NACE category. The service industry is defined as being from NACE category 50 to 93 inclusive.

Table 2: Summary Statistics of Innovation Outputs, 2004-2006

	All Firms (n=532)	Foreign Firms (n=131)	Exporters (n=203)	Domestic Firms (n=401)	Domestic Exporters (n=148)
All Innovations	0.61	0.70	0.70	0.58	0.69
Product Innovation	0.34	0.44	0.46	0.31	0.46
Process Innovation	0.30	0.35	0.35	0.29	0.34
Organisational Innovation	0.48	0.52	0.54	0.47	0.53
Patents	0.05	0.06	0.08	0.05	0.08

Notes: The summary statistics in each cell indicate the mean value for each of the binary innovation measures used in the analysis for different categories of firms in the sample. Foreign firms are defined as all firms with headquarters located outside the Republic of Ireland, all other firms are domestic. Exporters are firms that report a positive figure for exports. Domestic exporters are firms that have headquarters located in the Republic of Ireland and report a positive figure for exports. All innovation measures take a value of 0 or 1 depending on whether or not the firm reported an innovation (product, process or organisational innovation) or application for patents over the sample period. See Appendix A1 for detailed information about variables definitions and data sources.

Table 3: Summary Statistics of Innovation Inputs and Innovation Drivers, 2004-2006

	All Firms (n=532)	Foreign Firms (n=131)	Exporters (n=203)	Domestic Firms (n=401)	Domestic Exporters (n=148)
Engagement in In-House R&D	0.17	0.21	0.28	0.16	0.27
In-House R&D Expenditure	464.63	1564.80	1004.56	105.23	234.37
Engagement in Innovation	0.27	0.26	0.36	0.27	0.38
Total Innovation Expenditure	7185.25	10977.76	8314.15	5946.30	8517.17
Size	134.39	206.56	199.10	110.81	160.89
E-Sales	10.14	13.77	15.39	8.96	14.24
Web site	0.71	0.87	0.82	0.66	0.80
Wages per Employee	37364.56	46261.16	38636.80	34458.19	35407.11
Distance to the Global Technology Frontier	463317.00	358418.90	472658.70	497585.46	512224.60

Notes: The summary statistics in each cell indicate the mean value for each of the innovation input variables used in the analysis for different categories of firms in the sample. Foreign firms are defined as all firms with headquarters located outside the Republic of Ireland, all other firms are domestic. Exporters are firms that report a positive figure for exports. Domestic exporters are firms that have headquarters located in the Republic of Ireland and report a positive figure for exports. The variables Web site, Engagement in In-House R&D, and Engagement in Innovation are binary variables. E-sales is measured as a percentage of turnover from e-sales. Size is measured by total persons employed. Sales and wages figures are measured in thousands of Euros. Distance to the global technology frontier is measured as the difference between the productivity (sales per employee) of the top global firms (the 90th percentile) by industry and firm productivity. Negative values for the distance variable are normalised to one. See Appendix A1 detailed information about variables definitions and data sources.

Table 4: Summary Statistics of Knowledge Flows, 2004-2006

	All Firms (n=532)	Foreign Firms (n=131)	Exporters (n=203)	Domestic Firms (n=401)	Domestic Exporters (n=148)
Co-operation with other Enterprises within the Enterprise Group	0.09	0.18	0.09	0.05	0.07
Co-operation with Suppliers	0.10	0.11	0.12	0.10	0.14
Co-operation with Customers	0.07	0.08	0.10	0.07	0.11
Co-operation with Competitors	0.03	0.03	0.02	0.02	0.02
Co-operation with Consultants	0.04	0.02	0.05	0.04	0.06
Co-operation with Universities	0.04	0.06	0.03	0.03	0.03
Co-operation with Government	0.02	0.04	0.01	0.02	0.01

Notes: The summary statistics in each cell indicate the mean value for each of the binary co-operation measures used in the analysis for different categories of firms in the sample. Foreign firms are defined as all firms with a headquarters located outside the Republic of Ireland., all other firms are domestic. Exporters are firms that report a positive figure for exports. Domestic exporters are firms that have headquarters located in the Republic of Ireland and report a positive figure for exports. All co-operation measures take a value of one if the firm reported co-operation in innovation over the sample period and zero otherwise. See Appendix A1 for detailed definitions and data sources of variables.

Table 5: Innovation Input Equations

Dependent Variable	In-house R&D Expenditure	Total Innovation Expenditure
Size	0.586***	0.362***
	(0.103)	(0.076)
Distance to Technology Frontier	-0.034	-0.026
	(0.030)	(0.021)
Foreign-owned firm	0.065	-0.275
	(0.354)	(0.245)
Domestic exporter	1.303***	0.573***
	(0.351)	(0.213)
Industry Fixed Effects	Yes	Yes
Constant	Yes	Yes

Dependent Variable	Intensity of In-house R&D Expenditure	Intensity of Total Innovation Expenditure
Distance to Frontier	-0.021**	-0.051*
	(0.009)	(0.027)
Foreign-owned firm	0.104	-0.330
	(0.128)	(0.289)
Domestic exporter	0.471***	0.523*
	(0.157)	(0.301)
Industry Fixed Effects	Yes	Yes
Constant	Yes	Yes
Log likelihood	-366.596	-621.523
Bayesian Information Criterion	915.214	1437.623
N	532	532

*Notes: S*tandard errors in parentheses, clustered at industry level. *** Significant at 1% level, ** significant at 5% level, * significant at 10% level. Figures shown are marginal effects. The dependent variable in the first equation is a binary variable indicating whether or not the firm reported in-house R&D or innovation expenditure, respectively. The dependent variable in the second equation is the intensity of in-house R&D or innovation expenditure. Two-digit industry dummies are used to control for unobserved industry characteristics. See Appendix A1 for detailed definitions and data sources of variables.

Table 6: Innovation Output with In-House R&D Expenditure Intensity

	Product innovation	Process innovation	Organisat. innovation	Patents
Predicted R&D expenditure intensity	0.028 (0.134)	-0.079 (0.135)	0.222* (0.135)	-0.131 (0.441)
Foreign-owned	0.229 (0.253)	0.034 (0.272)	-0.246 (0.196)	-0.219 (0.800)
Domestic exporter	0.587** (0.242)	0.120 (0.241)	0.412* (0.216)	0.375 (0.801)
Size (log employment)	0.174*** (0.067)	0.233*** (0.073)	0.113** (0.046)	0.373* (0.214)
Log Wages per employee	0.223 (0.174)	-0.044 (0.184)	0.015 (0.122)	1.350** (0.593)
Distance to the global technology frontier (lagged)	-0.012 (0.022)	-0.004 (0.023)	0.038** (0.018)	0.022 (0.066)
Web-site	0.420** (0.184)	-0.054 (0.181)	0.198* (0.116)	1.647 (1.019)
E-sales	0.003 (0.003)	0.001 (0.003)	0.003 (0.002)	0.016* (0.008)
Co-operation with other enterprises	0.942** (0.452)	0.971** (0.390)	0.354 (0.259)	-0.981 (1.139)
Co-operation with suppliers	0.906*** (0.313)	1.021*** (0.293)	0.504** (0.198)	-0.540 (0.987)
Co-operation with customers	1.233*** (0.413)	0.287 (0.404)	0.049 (0.257)	1.132 (1.062)
Co-operation with competitors	-0.402 (0.585)	0.363 (0.593)	-0.116 (0.457)	2.357 (1.516)
Co-operation with consultants	-1.174** (0.465)	-0.187 (0.578)	0.359 (0.337)	1.218 (1.163)
Co-operation with universities	0.013 (0.788)	0.733 (0.745)	0.500 (0.490)	2.969** (1.307)
Co-operation with government	1.989* (1.032)	0.407 (0.758)	-0.128 (0.505)	-1.443 (1.704)
Industry fixed effects	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Log likelihood	-253.160	-268.933	-332.541	-75.283
$\chi 2$	100.260	68.168	52.814	73.338
N	522	530	530	457

Notes: Standard errors in parentheses, clustered at industry level. *** significant at 1% level, ** significant at 5% level, significant at 10% level. Figures shown in the table are marginal effects.

Table 7: Innovation Output with Total Innovation Expenditure

	Product innovation	Process innovation	Organisat. innovation	Patents
Predicted innovation expenditure intensity	-0.017 (0.085)	0.123 (0.103)	-0.165 (0.111)	0.221 (0.746)
Foreign-owned	0.259 (0.199)	-0.065 (0.222)	-0.002 (0.138)	-0.386 (0.664)
Domestic exporter	0.526** (0.216)	0.393* (0.233)	-0.115 (0.186)	0.852 (1.302)
Size (log employment)	0.174*** (0.067)	0.233*** (0.073)	0.113** (0.046)	0.373* (0.214)
Log Wages per employee	0.233 (0.174)	-0.044 (0.184)	0.015 (0.122)	1.350** (0.593)
Distance to the global technology frontier (lagged)	-0.016 (0.020)	0.013 (0.022)	0.003 (0.016)	0.052 (0.080)
Web-site	0.420** (0.184)	-0.054 (0.181)	0.198* (0.116)	1.647 (1.019)
E-sales	0.003 (0.003)	0.001 (0.003)	0.003 (0.002)	0.016* (0.008)
Co-operation with other enterprises	0.942** (0.452)	0.971** (0.390)	0.354 (0.259)	-0.981 (1.139)
Co-operation with suppliers	0.906*** (0.313)	1.021*** (0.293)	0.504** (0.198)	-0.540 (0.987)
Co-operation with customers	1.233*** (0.413)	0.287 (0.404)	0.049 (0.257)	1.132 (1.062)
Co-operation with competitors	-0.402 (0.585)	0.363 (0.593)	-0.116 (0.457)	2.357 (1.516)
Co-operation with consultants	-1.174** (0.465)	-0.187 (0.578)	0.359 (0.337)	1.218 (1.163)
Co-operation with universities	0.013 (0.788)	0.733 (0.745)	0.500 (0.490)	2.969** (1.307)
Co-operation with government	1.989* (1.032)	0.407 (0.758)	-0.128 (0.505)	-1.443 (1.704)
Industry fixed effects	Yes	Yes	Yes	Yes
Constant	Yes	Yes	Yes	Yes
Log likelihood	-253.160	-268.933	-332.541	-75.283
$\chi 2$	100.260	68.168	52.814	73.338
N	522	530	530	457

Notes: Standard errors in parentheses, clustered at industry level. *** significant at 1% level, ** significant at 5% level, significant at 10% level. Figures shown in the table are marginal effects.

Appendix A1: Variable Definitions and Data Sources.

Innovation Outputs

Variable Name	Source	**Variable Definition**
All Innovations	CIS	Binary variable equal to 1 if the firm introduced a product, process or organisational innovation and 0 otherwise
Product Innovation	CIS	Binary variable equal to 1 if the firm introduced a product innovation and 0 otherwise
Process Innovation	CIS	Binary variable equal to 1 if the firm introduced a process innovation and 0 otherwise
Organisational Innovation	CIS	Binary variable equal to 1 if the firm introduced an organisational innovation and 0 otherwise
Patents	CIS	Binary variable equal to 1 if the firm applied for a patent and 0 otherwise

Innovation Inputs

Variable Name	**Source**	**Variable Definition**
Size	AIS	Log of total persons engaged.
Log of wages pre employee	AIS	Log of wages and salaries per total persons engaged
Distance to the global technology frontier (2002)	AIS & ORBIS	The difference between the productivity (sales per employee) of the top global firms (the 90th percentile) by industry and firm productivit
Foreign-owned firm	CIS	Binary variable equal to 1 if the location of ownership is not Ireland and 0 otherwise
Domestic exporter	AIS	Binary variable equal to 1 if the location of ownership is Ireland and the firm reports a positive figure for exports and 0 otherwise
Web-site	AIS	Binary variable equal to 1 if the firm reports having a website and 0 otherwise
E-sales Turnover	AIS	Percentage of turnover from e-sales
In-house R&D	CIS	Binary variable equal to 1 if the firm reported positive in-house R&D expenditure and 0 otherwise
Total R&D	CIS	Binary variable equal to 1 if the firm reported positive total innovation expenditure and 0 otherwise
Intensity of in-house R&D	CIS	Log of expenditure on in-house R&D expenditure per employee
Intensity of total innovation expenditure	CIS	Log of total innovation expenditure per employee
Predicted R&D intensity (total)		Predicted value for total innovation expenditure for each firm from the Heckman estimation
Predicted R&D intensity (in-house)		Predicted value for in-house R&D expenditure for each firm from the Heckman estimation

Knowledge Flows

Variable Name	**Source**	**Variable Definition**
Co-operation with other Enterprises	CIS	Binary variable equal to 1 if the firm reports cooperation with other enterprises within their enterprise group and 0 otherwise
Co-operation with Suppliers	CIS	Binary variable equal to 1 if the firm reports cooperation with suppliers of equipment, materials, components or software and 0 otherwis
Co-operation with Customers	CIS	Binary variable equal to 1 if the firm reports cooperation with clients or customers in their innovation activities and 0 otherwise
Co-operation with Competitors	CIS	Binary variable equal to 1 if the firm reports cooperation with competitors or other enterprises in their sector and 0 otherwise
Co-operation with Consultants	CIS	Binary variable equal to 1 if the firm reports cooperation with consultants, commercial labs or private R&D institutes and 0 otherwise
Co-operation with Universities	CIS	Binary variable equal to 1 if the firm reports cooperation with universities or higher education institutions and 0 otherwise
Co-operation with Government	CIS	Binary variable equal to 1 if the firm reports cooperation with government or public research institutes and 0 otherwise

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