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The impact of investment in innovation on productivity: firm-level evidence from Ireland

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Abstract: This paper examines the relationship between investment in innovation and productivity across firms in Ireland. We estimate a structural model using information from three linked micro data sets over the period 2005-2012 and identify the relationships between investment in innovation, innovation outputs and productivity. Our results indicate that innovation is positively linked to productivity. This result holds for all types of innovation and for both R&D and non-R&D expenditures. The innovation-related productivity gains range from 16.2 per cent to 35.4 per cent. The strongest link between innovation and productivity is found for firms with R&D spending and with product innovation.

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1 Introduction

It is widely acknowledged that investment in innovation is a major driver of productivity growth.[2] However, not all firms invest in innovation and not all investments in innovation are translated directly into productivity gains. Existing international evidence has found that investment in innovation results in various innovation outputs such as product, process, organisational and marketing innovations which affect productivity via different channels.[3]

The objective of this analysis is to examine the relationship between investment in innovation and firm productivity in Ireland. To this purpose, we estimate a structural model which links investment in innovation to innovation outputs and productivity. More specifically, the following questions are addressed: (i) Which types of enterprises are more likely to invest in innovation and how much do they invest? (ii) Is spending on innovation translated into innovation outputs? (iii) Is firm productivity linked to innovation outputs?

We add to the literature on innovation and productivity at firm-level in three ways. Firstly, while most of existing evidence is based on cross-section data, we examine a panel data generated by linking information provided by Ireland's Central Statistics Office (CSO) from four waves of the Community Innovation Survey (CIS 2006, 2008, 2010, and 2012), annual data from the Census of Industrial Production (CIP) and the Annual Services Inquiry (ASI) over the period 2006-2012. The panel data allows us to account for persistence in the relationships we examine and to correct for endogeneity linked to reverse causality.[4] Secondly, we improve on the previous studies by estimating an augmented version of the widely used CDM model (Crépon, Duguet, Mairesse, 1998). The augmented version we estimate allows firms to implement jointly three types of innovation: product, process and organisational innovation. Thirdly, we link the three types of innovation inputs to three types of innovation expenditures: R&D expenditure only (expenditures for in-house R&D and expenditures for purchased R&D); non-R&D expenditures only (acquisitions of advanced machinery, equipment, software; acquisitions of other external knowledge such as purchased or licensed patented and non-patented inventions, know-how, and other types of knowledge from

[2] Recent evidence is reviewed among others by Syverson (2011), and Ruane and Siedschlag (2013).

[3] Recent international evidence has been reviewed by Hall (2011), and Siedschlag and Zhang (2015) among others.

[4] To the best of our knowledge, only a small number of country-specific studies have used panel data to analyse the links between investment in innovation and productivity. These include Parisi et al. (2006) for Italy, Raymond et al. (2010; 2015) for France and the Netherlands; Huergo and Moreno (2011) for Spain; Siedschlag and Zhang (2015) for Ireland; Hall and Sena (2017) for the UK. The linked data sets analysed in this paper cover a longer period than previous analyses for Ireland using panel data. For example Siedschlag and Zhang (2015) analysed the impact of investment in innovation on productivity across firms using a linked data set of two waves of the CIS (CIS 2006 and 2008) and annual data from the CIP and ASI over the period 2004-2008.

other enterprises and organisations for the development of new or significantly improved products and processes); and total innovation expenditures (combined R&D and non R&D expenditures).

Our results indicate that innovation is positively linked to labour productivity. This result holds for all types of innovation and all types of innovation expenditures (R&D and non-R&D expenditures). The productivity gains associated with the introduction of innovation outputs range from 16.2 per cent to 35.4 per cent. The strongest link between innovation and productivity is found for firms with R&D spending and with product innovation.

The remainder of this paper is organised as follows. Section 2 describes the data used for this analysis. Section 3 presents the empirical methodology. Next, Section 4, discusses the empirical results and Section 5 concludes and discusses policy implications drawn from the evidence provided in this paper.

2 Data and Descriptive Statistics

We use three linked micro data sets over the period 2005-2012 available from Irelands' Central Statistics Office: Community Innovation Survey (CIS), Census of Industrial Production (CIP), and Annual Services Inquiry (ASI). The data matching has been done using the common firm identifier provided by the CSO.

The information on innovation expenditures collected with the CIS include *R&D expenditures* (in-house R&D[5] and purchased external R&D) as well as *non-R&D expenditures* (acquisitions of advanced machinery, equipment, software; acquisitions of other external knowledge such as purchased or licensed patented and non-patented inventions, know-how, and other types of knowledge from other enterprises and organisations for the development of new or significantly improved products and processes).

Figures 1 and 2 describe patterns and trends of firms' R&D and non-R&D expenditures over the period 2006-2012 broken down by ownership, export participation and size class. This analysis is based on weighted data from the CIS 2006, 2008, 2010, and 2012. The firm-level weights are computed using grossing factors for the number of firms provided by the CSO. Tables A1 and A2 in the Appendix report detailed descriptive statistics broken down for the categories of firms considered.

Looking first at Figure 1, a common pattern across all firms as well as Irish and foreign-owned firms is the higher share of firms with R&D expenditure for firms engaged in exporting in comparison to

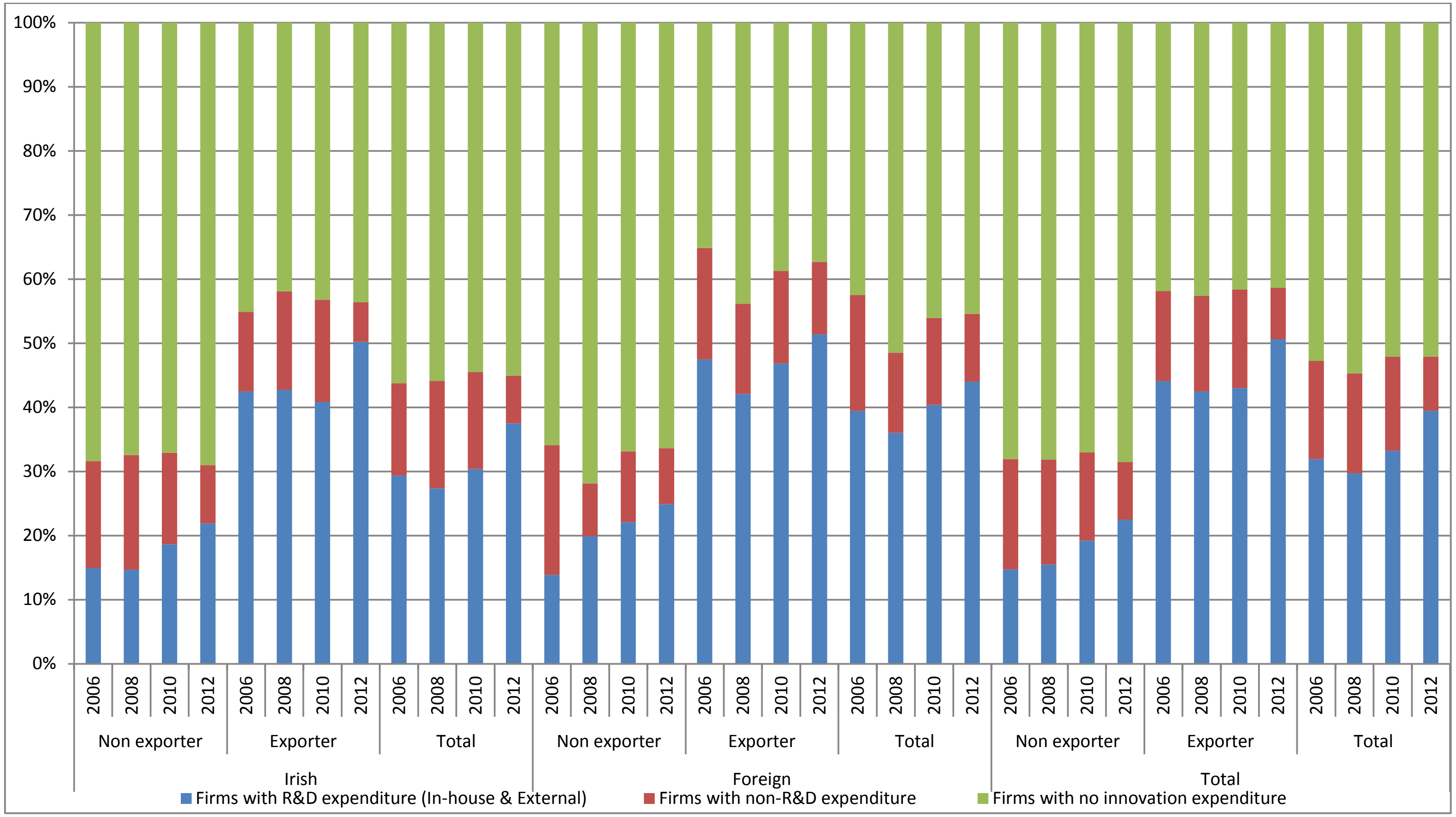
[5] Capital expenditures on buildings and equipment specifically for R&D and current expenditures for creative work for developing product and process innovations (including software developed in-house for creative work).

firms serving only the Irish market. It is also noteworthy that the proportion of firms with R&D expenditure has increased over the analysed period, 2006-2012 across all three categories of firms. The share of firms with R&D expenditure in the case of exporters ranges from 44 to 51 per cent, among all firms; from 43 to 50 percent among Irish-owned firms, and from 48 to 51 per cent in the case of foreign-owned firms. In the case of firms serving only the Irish market, the share of firms with R&D expenditure ranges from 15 to 22 per cent for Irish-owned firms and from 14 to 25 per cent in the case of foreign-owned firms. In contrast, the shares of firms with non-R&D expenditures do not differ too much across exporters and non-exporters. They also seem to be similar across Irish and foreign-owned firms. In addition, it seems that the increase over time of the share of firms with R&D expenditure, in particular at the end of the period has been accompanied by a decline of the share of firms with non-R&D expenditure. Taking together R&D and non R&D expenditures, at the end of the period (in 2012) the share of firms with expenditure on innovation was 56 percent among Irish exporters (higher by 3 percentage points than in 2006), and 63 per cent among foreign-owned exporters (lower by 2 percentage points compared to 2006).

Figure 2 shows that the share of firms with R&D expenditure is increasing with firm size. This pattern is in general consistent across all firms as well as Irish- and foreign-owned firms. In 2012, for Irish-owned large firms the share of firms with R&D expenditure is lower than in the middle-sized group. This pattern is due to an increase by 12 percentage points of the share of medium-sized firms with R&D expenditure in 2012 compared with 2006 which has been mirrored by a decrease by 11 percentage points of the share of large firms with R&D expenditure. In the case of foreign-owned firms, large firms are clearly ahead of the small and medium-sized firms with respect to the proportion of firms with R&D expenditure. In 2012, 70 percent of large firms had R&D expenditures compared to 45 per cent and 30 percent in the case of medium-sized and small foreign-owned firms, respectively.

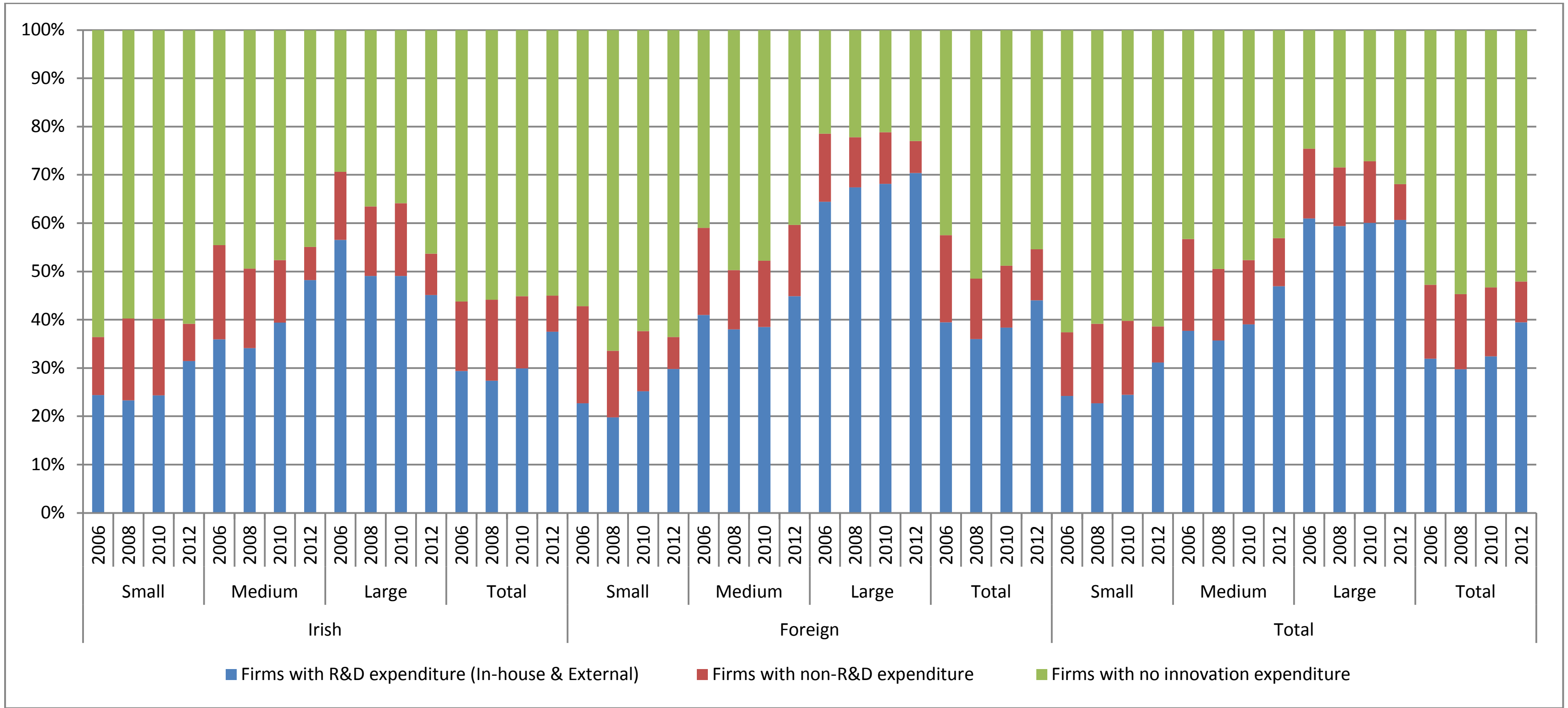
Fig. 3 shows the distribution of productivity measured as value added per employee for firms with R&D and non-R&D expenditures and for firms with no innovation expenditure. At low levels of productivity, the number of firms with no innovation expenditures is higher than the number of firms with R&D and with non-R&D expenditures. As the productivity increases, the number of firms with R&D expenditure is higher than the number of firms with non-R&D expenditures and the number of firms with no innovation expenditure.

Figure 1: The share of firms with R&D and with non-R&D expenditures in total firms, by ownership and export participation



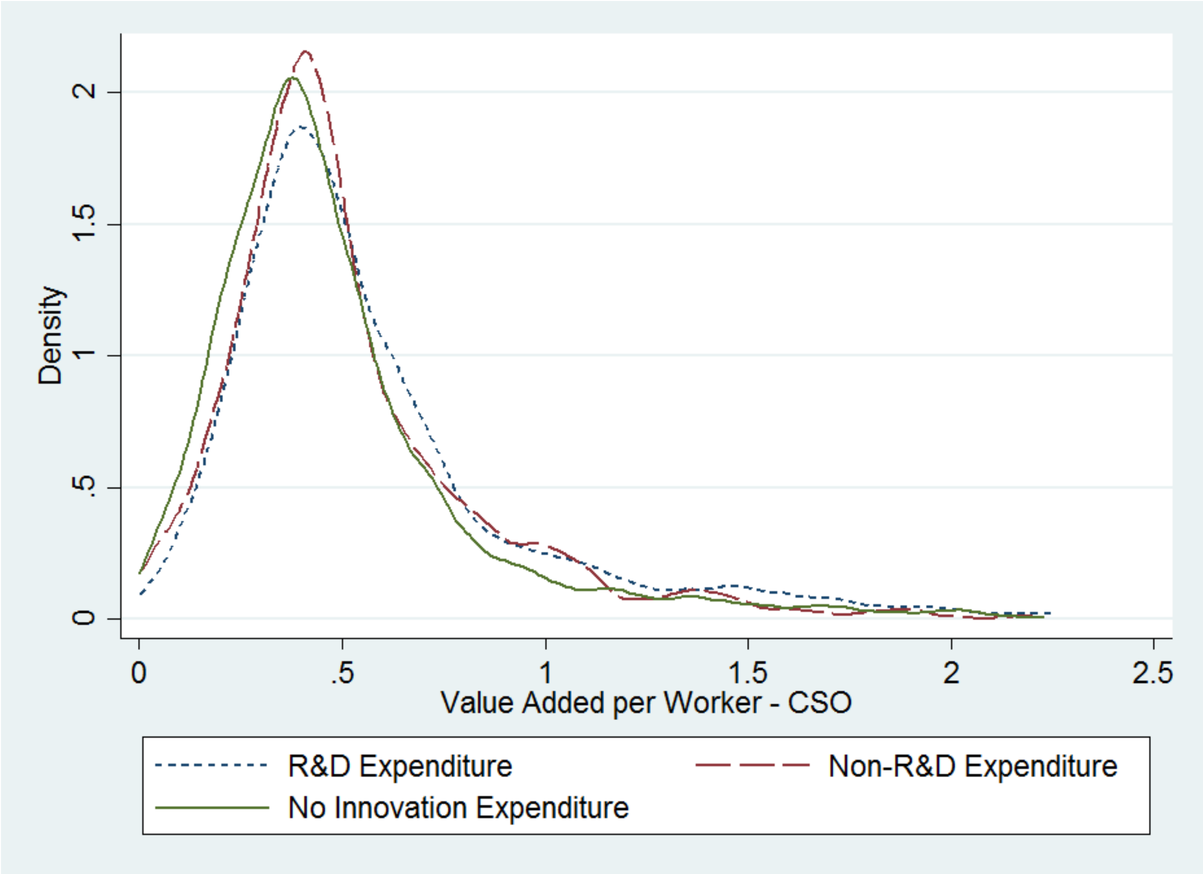
Source: Authors' calculations based on linked micro-data from the CIS, CIP and ASI data sets. The data is weighted using firm-level weights based on grossing factors for the number of firms provided by the CSO.

Figure 2: The share of firms with R&D and with non-R&D expenditures in total firms, by ownership and size class



Source: *A*uthors' calculations based on linked micro-data from the CIS, CIP and ASI data sets. The data is weighted using firm-level weights based on grossing factors for the number of firms provided by the CSO.

Figure 3: The productivity distribution of firms with innovation and with no innovation expenditure



Source: Authors' estimates based on linked micro-data from the CIS, CIP and ASI data sets.

3 Empirical Methodology

Our empirical analysis uses an econometric structural model which links investment in innovation, innovation outputs and productivity. The estimated model is an augmented version of the model developed by Crépon, Duguet and Mairesse (1998) known as the CDM model.[6]

The CDM model estimates three sets of relationships. The first set consists of two equations relating to the investment phase, namely the propensity of enterprises to invest in innovation and the innovation expenditure intensity conditional on spending on innovation. The second set relates the various types of innovation outcomes to innovation expenditure intensity (innovation expenditure per employee) and other enterprise and industry characteristics. The third set links output/productivity to innovation outcomes and other enterprise characteristics.

[6] Previous analyses of the links between innovation and productivity based on modified versions of the CDM model for firms in Ireland include Siedschlag et al. (2011), Ruane and Siedschlag (2013), Peters et al. (2014), and Siedschlag and Zhang (2015).

The original CDM model was estimated for innovative firms only. To account for the fact that the group of innovators might not be random, we extend a modified version of the CDM model proposed by Griffith et al. (2006) that controls for this selection bias. The econometric model is described below. Detailed definitions of the variables used in the analysis are given in Table B1.

The Innovation Investment Equations

This stage of the model comprises two equations which explain the firms' decision to invest/not invest in innovation and, if investing, the amount of innovation expenditure per employee. We only observe the innovation expenditure reported by firms. However, this group of firms may not be random implying a selection bias. To account for this potential bias, the propensity of firms to invest in innovation is estimated on the basis of the following selection equation:

$$y_{ijt}=\begin{cases}1 \ if \ y^*_{ijt}=X_{ijt}\gamma+\lambda_j+\mu_t+\varepsilon_{ijt}>\tau \\ 0 \ if \ y^*_{ijt}=X_{ijt}\gamma+\lambda_j+\mu_t+\varepsilon_{it}\le\tau\end{cases} \tag{1}$$

y_{ijt} is an observed binary variable which equals one if firm *i* in industry *j* is engaged in innovation investment at time *t* and zero otherwise. Firms engage in innovation and/or report innovation expenditure if the unobserved latent variable y^*_{ijt} corresponding to investment in innovation is above a certain threshold level τ . X_{ijt} is a vector of firm-level variables explaining the innovation decision, γ is the vector of parameters, λ_j is an industry-specific effect, μ_t is a time-specific effect and ε_{ijt} is the error term.

Conditional on investing in innovation, the amount of innovation expenditure per employee (w_{ijt}) is given by the following equation:

$$w_{ijt}=\begin{cases}w^*_{ijt}=Z_{ijt}\beta+\lambda_j+\mu_t+\omega_{ijt}, \ if \ y_{ijt}=1 \\ 0 \ if \ y_{ijt}=0\end{cases} \tag{2}$$

w^*_{ijt} is the unobserved latent variable reflecting the intensity of investment in innovation, Z_{ijt} is a vector of firm characteristics and ω_{ijt} is an error term.

Following Griffith et al. (2006), under the assumption that the error terms in equations (1) and (2) follow a bivariate normal distribution with mean zero (variances $\sigma^2_\varepsilon=1$ and σ^2_ω), equations (1) and (2) can be estimated as a generalised Tobit model using a Heckman procedure.

The Innovation Output Equations

This second stage of the model explains the innovation outcomes given by the following knowledge production function:

$$g_{ijt} = \overline{w_{ijt}}\alpha + H_{ijt}\delta + \lambda_j + \mu_t + \nu_{ijt} \tag{3}$$

where g_{ijt} is innovation output proxied by product, process, and organisational innovation indicators. $\overline{w_{ijt}}$ is the predicted innovation expenditure per employee estimated from the model described by Equations (1) and (2). These values are predicted for all firms and not just the sample reporting innovation expenditure. By using the predicted values of this variable to instrument the innovation effort (w_{ijt}), we account for the possibility that innovation expenditure per employee and the innovation outputs could be simultaneously determined. The selection and innovation expenditure intensity equations (1) and (2) thus correct for this endogeneity. H_{ijt} is a vector of other determinants of innovation output, α and δ are the parameter vectors, λ_j is an industry-specific effect, μ_t is a time-specific effect, and ν_{ijt} is the error term.

Following on from a literature strand on the complementarity of different types of innovations initiated by Milgrom and Roberts (1990, 1995), [7] we model the probability that firms introduce product, process and organisational innovations jointly. To this purpose, we estimate a tri-variate probit model which allows the error terms in the three innovation output equations to be correlated. The system of three simultaneous equations to be estimated is as follows:

$$\begin{pmatrix} g_{ijt}^{Product} \\ g_{ijt}^{Process} \\ g_{ijt}^{Organisational} \end{pmatrix} = \varphi \begin{pmatrix} \overline{w_{1ijt}} + H_{1ijt}\delta_1 + \lambda_j + \mu_t + \nu_{1ijt} \\ \overline{w_{2ijt}} + H_{2it}\delta_2 + \lambda_j + \mu_t + \nu_{2ijt} \\ \overline{w_{3ijt}} + H_{3ijt}\delta_3 + \lambda_j + \mu_t + \nu_{3ijt} \end{pmatrix} \tag{4}$$

The Output Production Equation

The last stage of the model explains the output production as a function of labour, capital, and innovation outcomes as follows:

$$p_{ijt} = k_{ijt}\zeta + \overline{g_{ijt}}\vartheta + \lambda_j + \mu_t + \upsilon_{ijt} \tag{5}$$

[7] Mairesse and Robin (2008) use a bivariate probit model to model the joint introduction of product and process innovations. Other studies on complementarities in firms' innovation activity include Polder et al. (2010), Hall, Lotti, and Mairesse (2013), and Bartelsman et al. (2017).

p_{ijt} is labour productivity (log of output per employee), k_{it} is the log of physical capital per worker and $\overline{g_{ijt}}$ denotes the predicted innovation probabilities (for product, process, organisational innovation), ζ and ϑ are vectors of parameters, λ_j is an industry-specific effect, μ_t is a time-specific effect, and υ_{ijt} is the error term. Using the predicted innovation probabilities on the basis of the system of simultaneous equations (4) corrects for the fact that productivity and innovation output could be simultaneously determined.

4 Empirical Results

Columns 1, 3, and 5 in Table 1 show the estimates of determinants of the propensity of firms to invest in innovation based on the model (1) described above. The model is estimated separately for R&D spending, spending on non-R&D assets and total innovation expenditure (spending on R&D and non-R&D assets). On the basis of recent studies using the CDM model,[8] the explanatory variables of the likelihood to invest in innovation (selection equation) include foreign ownership export intensity, wage per employee (a proxy for human capital), market share (a proxy for competition), perceived internal and external financing constraints[9], age and age squared, total number of employees (a proxy for firm size) and engagement in co-operation for innovation activities.

The results in Column 1 indicate that firms which are more likely to invest in R&D are those which are larger, Irish-owned, with large export intensity (measured as export sales per employee), and firms engaged in co-operation for innovation activities. The propensity of firms to invest in R&D is higher in industries with better access to external financing and in industries in which innovation is perceived to be constrained by the lack of internal financing. This latter result could be linked to the fact that firms investing in R&D are more likely to perceive the lack of internal financing as a constraint to innovation relative to firms with no R&D investment.[10] Furthermore, this result might be explained by the fact that small firms which are likely to be more financially constrained than larger firms[11] are underrepresented in the CIS data.[12] This implies that the result of a positive link

[8] Recent studies using the CDM model have been reviewed by Hall (2011), Ruane and Siedschlag (2013) and Siedschlag and Zhang (2015).

[9] We follow Hall and Sena (2017) and construct measures of perceived internal and external financing constraints at industry level (at the 3 digit NACE Rev. 2 classification).

[10] Similar results have been found in other analyses of the effect of financing constraints on investment in innovation and innovation performance using data from the Community Innovation Surveys (CIS). See for example Mohnen and Röller (2005) using data from Ireland, Denmark, Germany and Italy, Mohnen et al. (2008) for the Netherlands, Savignac (2008) for France, Silva and Carreira (2012) for Portugal, and Hall and Sena (2017) for the UK.

[11] See for example Hall and Lerner (2009).

[12] This point is made by Mohnen et al. (2008).

between financing constraints and investment in innovation is likely to be driven by the larger firms, without being necessary representative for all firms, for small firms in particular.

As shown in Column 3, firms' propensity to invest in non-R&D assets is higher for Irish-owned firms relative to foreign-owned firms, firms engaged in co-operation for innovation activities, and it is increasing in firms' size and export intensity. Taking together R&D and non-R&D investments, the results in Column 5 indicate that the propensity of firms to invest in innovation is higher for Irish-owned firms, larger firms, firms with a higher export intensity, firms with a higher human capital/skills intensity. Firms in industries with better access to external financing and in industries in which innovation is perceived to be constrained by the lack of internal financing are more likely to invest in both R&D and non-R&D assets.

Following previous studies, we model the intensity of innovation expenditure as a function of the same variables included in the selection equation excluding for identification purposes: firm size, age, age squared, and engagement in co-operation for innovation activities. We add labour productivity lagged by one year to account for firms' innovation capability.

Columns 2, 4, and 6 in Table 1 above show the estimates on determinants of firms' intensity of investment in innovation separately for R&D spending, non-R&D spending, and innovation expenditures including spending on both R&D and non R&D inputs. The model specification is described by model (2) above.

The results indicate that after controlling for firm characteristics, innovation expenditures per employee, R&D as well as non-R&D expenditures are not significantly different in foreign-owned than in Irish-owned firms. The intensity of R&D expenditures increases with export intensity and skills intensity. Firms facing more competition spend more on R&D per employee. More productive firms which have a higher innovation capability spend more on R&D as well as non-R&D per employee. Finally, total innovation expenditures per employee are higher in industries where innovation is perceived to be constrained by the lack of internal finance and in industries with a low average perceived market risk.

Table 1: Determinants of firms' propensity to invest in innovation

	(1)	(2)	(3)	(4)	(5)	(6)
	R&D expenditure		Non-R&D expenditure		Total innovation exp.	
Dependent variables	Pr.(R&D)	Ln(R&D/Emp.)	Pr.(Non-R&D)	Ln(Non-R&D/Emp.)	Pr.(Inn. Exp.)	Ln(Total Inn. Exp./Empl)
Equation	*Selection*	*Intensity*	*Selection*	*Intensity*	*Selection*	*Intensity*
Foreign ownership	-0.360***	0.008	-0.167***	0.006	-0.285***	0.022'
	(0.097)	(0.010)	(0.062)	(0.010)	(0.084)	(0.014)
Ln(Export Intensity)$_{t-1}$	1.048***	0.073***	0.358***	0.005	0.766***	0.049'
	(0.149)	(0.019)	(0.109)	(0.018)	(0.145)	(0.031)
Ln(Wage/Employee)$_{t-1}$	0.408	0.234***	-0.177	0.062	0.649**	0.290***
	(0.351)	(0.063)	(0.255)	(0.048)	(0.323)	(0.093)
Market Share$_{t-1}$	-0.152	-0.165**	0.066	0.056	-0.129	0.028
	(0.549)	(0.064)	(0.371)	(0.062)	(0.541)	(0.114)
Average perceived internal fin. constraints (3-digit ind.)	0.888***	0.025	0.147	0.012	0.638***	0.065**
	(0.197)	(0.018)	(0.141)	(0.028)	(0.195)	(0.026)
Average perceived external fin. constraints (3-digit ind.)	-0.562***	-0.007	-0.111	-0.029	-0.446**	-0.042
	(0.198)	(0.020)	(0.141)	(0.028)	(0.196)	(0.035)
Average perceived market risk (3-digit ind.)	0.140	0.009	0.123	-0.017	0.244'	-0.045*
	(0.167)	(0.016)	(0.103)	(0.021)	(0.149)	(0.026)
Ln(Value Added/Emp.$_{t-1}$)		0.029*		0.028***		0.024'
		(0.016)		(0.007)		(0.015)
Ln(Age)	4.201'		0.518		3.005	
	(2.647)		(1.979)		(2.383)	
Ln(Age squared)	-1.901'		-0.295		-1.388	
	(1.179)		(0.882)		(1.061)	
Ln(Employees)	0.244***		0.131***		0.181***	
	(0.040)		(0.029)		(0.040)	
Cooperation for innovation	1.143***		0.775***		1.238***	
	(0.078)		(0.060)		(0.083)	
Constant	-4.753***	-0.104'	-1.274*	-0.012	-3.527***	-0.130
	(1.009)	(0.065)	(0.749)	(0.115)	(0.906)	(0.115)
Industry group dummies[a]	Yes	No	Yes	No	Yes	No
NACE 2-digit FE	No	Yes	No	Yes	No	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	2914	2914	2917	2917	2911	2911

Source: Authors' estimates based on data from the linked CIS, CIP and ASI data sets, 2005-2012.

Notes: Robust standard errors clustered at the firm level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01. Value Added was calculated as the difference between turnover and the cost of material and services. Results in columns 1, 2, 5 and 6 were obtained with the maximum likelihood Heckman estimator; results in column 3 and 4 were obtained with the two-step Heckman estimator, because of the lack of convergence of the maximum likelihood estimator. [a] representing industry groups by technology intensity in manufacturing and services sectors, according to the Eurostat classification, http://europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

Table 2 reports the estimates for the likelihood of innovation outputs including product, process and organisational innovations. These estimates are obtained with model (4) described above. The explanatory variables include the predicted intensity of innovation expenditures (R&D, non-R&D and combined R&D and non-R&D), export intensity, import intensity, investment in tangibles per employee, perceived external financial constraints, perceived market risk[13], foreign ownership, age and age squared, firm size, and engagement in co-operation for innovation activity.

The results indicate that firms with a higher R&D expenditure per employee are more likely to introduce product and process innovations. Firms with a higher intensity of non-R&D expenditures are more likely to introduce process innovations. When total innovation expenditure per employee is considered, we find a positive but statistically not significant relationship with the likelihood of innovation outputs. Taken together these results suggest that the relationship between the likelihood of innovation outputs and innovation expenditure intensity is stronger in the case of product and process innovation and weaker in the case of organisational innovation.

Larger firms, firms engaged in co-operation for innovation, and firms in industries with a higher perceived market risk are more likely to introduce innovation outputs. These effects are large and statistically significant across the three types of innovation expenditures considered for all types of innovations. The importance of other factors considered vary across the three types of innovations and innovation expenditures. Export intensity is positively linked to the likelihood to introduce product innovations. The relationship appears to be stronger in the case of firms with non-R&D expenditures only and when total innovation expenditures are considered. Firms with a higher import intensity are more likely to introduce organisational innovations. These results hold across all three types of innovation expenditures (R&D only, non-R&D only, and total innovation expenditures). Finally, firms with a higher intensity of investment in tangible capital are more likely to introduce process innovations.

[13] Tiwari et al. (2007) suggest that perceived financing constraints interact with perceived market risk in conditioning firms' innovation performance. Hall and Sena (2017) follow this suggestion as well.

Table 2: The impact of spending on R&D and non-R&D inputs on innovation outputs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	R&D expenditure			**Non-R&D expenditure**			**Total innovation expenditure**		
Dependent variables	Product Innovation	Process Innovation	Organizational Innovation	Product Innovation	Process Innovation	Organizational Innovation	Product Innovation	Process Innovation	Organizational Innovation
R&D/employee (predicted)	2.655***	1.452**	0.675						
	(0.718)	(0.730)	(0.677)						
Non-R&D/employee (predicted)				0.153	1.760**	0.474			
				(0.559)	(0.803)	(0.452)			
Inn. Exp./employee (predicted)							0.649	0.556	0.482
							(0.727)	(0.597)	(0.587)
Ln(Export Intensity)$_{t-1}$	0.222	-0.193	0.139	0.447***	-0.087	0.192	0.407***	-0.096	0.169
	(0.161)	(0.162)	(0.158)	(0.150)	(0.152)	(0.151)	(0.158)	(0.155)	(0.154)
Ln(Import Intensity)$_{t-1}$	-0.072	-0.178	0.682***	0.054	-0.125	0.710***	0.004	-0.182	0.673***
	(0.274)	(0.246)	(0.250)	(0.270)	(0.245)	(0.249)	(0.263)	(0.250)	(0.253)
Ln(Tangibles/employee)	0.028	0.526**	0.018	0.173	0.507**	0.032	0.136	0.556***	0.016
	(0.206)	(0.212)	(0.241)	(0.200)	(0.210)	(0.238)	(0.203)	(0.212)	(0.241)
				(0.139)	(0.121)	(0.114)	(0.141)	(0.120)	(0.114)
Perceived external financial constraints	-0.048	-0.052	0.110	-0.051	-0.057	0.109	-0.049	-0.044	0.118
	(0.126)	(0.109)	(0.107)	(0.123)	(0.109)	(0.106)	(0.124)	(0.108)	(0.106)
Perceived market risk	0.541***	0.360***	0.343***	0.535***	0.365***	0.344***	0.531***	0.365***	0.349***
	(0.102)	(0.088)	(0.091)	(0.100)	(0.088)	(0.091)	(0.101)	(0.088)	(0.091)
Foreign ownership	-0.015	-0.059	-0.007	0.048	-0.058	0.001	0.029	-0.038	0.012
	(0.090)	(0.089)	(0.080)	(0.087)	(0.089)	(0.079)	(0.091)	(0.090)	(0.083)
Ln(Age)	0.554	0.876	1.952	0.417	0.799	1.929	0.173	0.628	1.856
	(2.588)	(2.389)	(2.408)	(2.575)	(2.399)	(2.407)	(2.581)	(2.391)	(2.434)
Ln(Age squared)	-0.298	-0.438	-0.916	-0.233	-0.403	-0.906	-0.125	-0.323	-0.866
	(1.151)	(1.062)	(1.072)	(1.145)	(1.067)	(1.072)	(1.148)	(1.063)	(1.084)
Ln(Employees)	0.227***	0.197***	0.244***	0.223***	0.193***	0.243***	0.222***	0.194***	0.237***
	(0.039)	(0.042)	(0.038)	(0.039)	(0.042)	(0.038)	(0.039)	(0.042)	(0.039)
Cooperation	1.109***	1.023***	0.924***	1.120***	1.024***	0.926***	1.113***	1.023***	0.915***
	(0.085)	(0.085)	(0.087)	(0.085)	(0.086)	(0.086)	(0.085)	(0.086)	(0.088)
Corr. (Product, Process)	0.384***			0.389***			0.365***		
	(0.048)			(0.048)			(0.046)		
Corr. (Product, Organizational)	0.242***			0.244***			0.205***		
	(0.045)			(0.045)			(0.045)		
Corr. (Process, Organizational)	0.491***			0.491***			0.486***		
	(0.045)			(0.045)			(0.044)		
Constant	-2.687***	-1.766**	-2.264**	-2.604***	-1.780**	-2.270**	-2.578***	-1.738*	-2.304**
	(0.983)	(0.887)	(0.920)	(0.983)	(0.890)	(0.919)	(0.990)	(0.890)	(0.928)
Sector technology dummies[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N observations	2390	2390	2390	2390	2390	2390	2390	2390	2390

Source: Authors' estimates based on data from the linked CIS, CIP and ASI data sets, 2005-2012. *Notes*: Robust standard errors clustered at the firm level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01. The method of estimation is simulated maximum likelihood (with 10 draws) on a trivariate probit model.[a]: Industry groups defined on the basis of technology intensity in manufacturing and services sectors, according to Eurostat classification, http://europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

Table 3 shows the estimated relationships between innovation outputs and productivity. The model specification is described by Equation (5). The dependent variable in the productivity models is the one-year forward value added per employee in logs. The explanatory variables include the predicted probabilities to introduce innovations (product, process and organisational innovations), investment in tangible assets per employee, age and age squared, and a set of categorical variables for firms' engagement in international trade (the reference category is indigenous firms serving only the Irish market).

Taken together, the results indicate that innovation outputs are positively linked to labour productivity. This result holds for all types of innovation outputs and all types of investment in innovation (spending on R&D and on non-R&D assets). The productivity gains associated with innovation over the analysed period, 2006-2012 range from 16.2 per cent to 35.4 per cent. The strongest link between innovation and productivity is found for firms with R&D spending and with product innovation. Relative to firms with no innovation outputs, labour productivity in firms with product innovations is on average higher by 35.4 per cent. In the case of firms with non-R&D expenditure, relative to non-innovators, labour productivity in firms with process innovation is higher on average by 27.1 per cent while organisational innovation increases productivity by 21.3 per cent. In the case of firms with both R&D and non-R&D expenditure, the labour productivity elasticity is highest for organisational innovation, 21.9 per cent.

A number of additional results are worth discussing. Productivity is positively linked to the intensity of investment in tangible fixed assets across all models. Irish-owned firms with importing activity are more productive than firms serving only the Irish-market. This result is also obtained for all types of innovations and all types of innovation expenditures considered. With the exception of firms with R&D expenditure only and product innovation, Irish-owned firms with both importing and exporting activity are more productive than Irish-owned firms with no international activity. Regardless of their engagement in international trade, foreign-owned firms are more productive than Irish-owned firms across all types of estimated models.

All models control for time-specific industry-specific shocks which are common across all firms.

Table 3: The impact of innovation on productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable Value added per employee in t+1	**R&D expenditure**			**Non-R&D expenditure**			**Total innovation expenditure**		
Product Innovation (predicted probability)	0.354***			0.162**			0.202***		
	(0.073)			(0.075)			(0.075)		
Process Innovation (predicted probability)		0.277***			0.271***			0.190**	
		(0.080)			(0.080)			(0.081)	
Organisational Innovation (predicted probability)			0.243***			0.213***			0.219***
			(0.081)			(0.082)			(0.082)
Ln(Tangibles/employee)	1.171***	1.140***	1.190***	1.194***	1.144***	1.193***	1.189***	1.164***	1.193***
	(0.220)	(0.222)	(0.223)	(0.224)	(0.223)	(0.224)	(0.224)	(0.224)	(0.224)
Ln(Age)	-0.052	-0.034	-0.079	0.102	-0.026	-0.040	0.086	0.063	-0.041
	(1.101)	(1.103)	(1.097)	(1.104)	(1.103)	(1.098)	(1.104)	(1.103)	(1.098)
Ln(Age squared)	0.050	0.042	0.061	-0.020	0.038	0.044	-0.012	-0.002	0.044
	(0.491)	(0.492)	(0.489)	(0.492)	(0.492)	(0.490)	(0.492)	(0.492)	(0.490)
Irish Importer	0.095*	0.099*	0.096*	0.102*	0.099*	0.097*	0.101*	0.102*	0.097*
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
Irish Exporter	0.113	0.137'	0.134'	0.139'	0.138'	0.138'	0.134'	0.145*	0.137'
	(0.083)	(0.084)	(0.084)	(0.085)	(0.084)	(0.084)	(0.084)	(0.085)	(0.084)
Irish Importer-Exporter	0.073'	0.093**	0.086*	0.098**	0.093**	0.090**	0.093**	0.101**	0.089*
	(0.046)	(0.045)	(0.046)	(0.046)	(0.045)	(0.046)	(0.046)	(0.045)	(0.046)
Foreign non trader	0.539***	0.557***	0.560***	0.562***	0.558***	0.562***	0.557***	0.564***	0.561***
	(0.135)	(0.136)	(0.136)	(0.136)	(0.136)	(0.136)	(0.136)	(0.136)	(0.136)
Foreign Importer	0.396***	0.420***	0.408***	0.422***	0.421***	0.413***	0.417***	0.428***	0.411***
	(0.127)	(0.128)	(0.129)	(0.130)	(0.128)	(0.129)	(0.129)	(0.129)	(0.129)
Foreign Exporter	0.365***	0.406***	0.399***	0.403***	0.407***	0.404***	0.395***	0.415***	0.402***
	(0.136)	(0.136)	(0.137)	(0.137)	(0.136)	(0.137)	(0.137)	(0.136)	(0.137)
Foreign Importer-Exporter	0.375***	0.416***	0.401***	0.412***	0.416***	0.407***	0.404***	0.425***	0.404***
	(0.068)	(0.067)	(0.069)	(0.070)	(0.067)	(0.070)	(0.070)	(0.067)	(0.070)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NACE 2-dig. sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2172	2172	2172	2172	2172	2172	2172	2172	2172

*Source: A*uthors' estimates based on data from the linked CIS, CIP and ASI data sets, 2005-2012.
Note: Robust standard errors clustered at the firm level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.

5 Conclusions and Policy Implications

This paper examines the links between investment in innovation, innovation outputs and productivity across firms in Ireland. The empirical analysis is based on estimates obtained with a structural model using a panel of annual data over the period 2005-2012. The key findings are summarised below.

Firms which are more likely to invest in R&D are those which are larger, Irish-owned, with large export intensity (measured as export sales per employee), and firms engaged in co-operation for innovation activities. Furthermore, the propensity of firms to invest in R&D is higher in industries with better access to external financing. We also find that firms in industries in which internal financing for innovation is perceived as constrained are more likely to invest in R&D. This result and similar findings for the propensity of firms to invest in both R&D and non-R&D assets, as well as for the intensity of innovation expenditures reported below could be explained by the fact that firms engaged in innovation are more likely to be aware of financing constraints. Similar results indicating a positive link between perceived financing constraints and investment in innovation using data from the Community Innovation Surveys have been reported in other country studies (see for example, Savignac 2008 for France; Silva and Carreira 2012 for Portugal; Hall and Sena 2017 for the UK) as well as cross-country analysis (Mohnen and Röller 2005, using data from Ireland, Denmark, Germany and Italy). Further research using richer information on firms' financing conditions could shed more light on the extent to which investment in innovation is conditioned by access to finance.

Further, our results indicate that firms' propensity to invest in non-R&D assets is higher for Irish-owned firms relative to foreign-owned firms, firms engaged in co-operation for innovation activities, and it is increasing in firms' size and export intensity.

Taking together R&D and non-R&D investments, the propensity of firms to invest in innovation is higher for Irish-owned firms, larger firms, firms with a higher export intensity, firms with a higher human capital/skills intensity, firms in industries with better access to external financing and in industries in which internal financing for innovation is constrained.

Over and above other firms characteristics, innovation expenditures per employee (R&D as well as non-R&D expenditures) are positively associated with export intensity (export sales per employee), and skills intensity. More productive firms which have a higher innovation capability spend more on R&D as well as non-R&D per employee. Finally, total innovation expenditures per employee are higher in industries in which innovation is perceived as being constrained by the lack of internal financing and in industries with a low average perceived market risk.

The research results indicate a strong positive link between the intensity of R&D expenditures and the likelihood to introduce product innovations and process innovations while the intensity of non-R&D expenditures is positively linked to the probability to introduce process innovations.

The likelihood of innovation outputs vary across firms and across industries. Larger firms, firms engaged in co-operation for innovation, and firms in industries with a higher perceived market risk are more likely to introduce innovation outputs. These effects are large and statistically significant across the three types of innovation expenditures considered and for all types of innovations. The importance of other factors considered vary across the three types of innovations and innovation expenditures. The likelihood to introduce product innovations is positively linked to export intensity. The relationship appears to be stronger in the case of firms with non-R&D expenditures only and when total innovation expenditures are considered. Firms with a higher import intensity are more likely to introduce organisational innovations. This result holds across all three types of innovation expenditures (R&D only, non-R&D only, and total innovation expenditures). Finally, firms with a higher intensity of investment in tangible capital are more likely to introduce process innovations.

The results of this analysis indicate that innovation is positively linked to labour productivity across all types of innovation and all types of innovation expenditures (R&D and non-R&D). The productivity gains associated with introducing innovation outputs over the analysed period, 2006-2012 range from 16.2 per cent to 35.4 per cent. The strongest link between innovation and productivity is found for firms with R&D spending and with product innovation. For these firms, introducing product innovations is linked to an increased labour productivity by 35.4 per cent.

Productivity is positively linked to the intensity of investment in tangible fixed assets across all models. Irish-owned firms with importing activity are more productive than firms serving only the Irish-market. With the exception of firms with R&D expenditure only and with product innovation, Irish-owned firms with both importing and exporting activity are more productive than Irish-owned firms with no international activities. Regardless of their engagement in international trade, foreign-owned firms are more productive than Irish-owned firms across all types of estimated models.

It is widely acknowledged that given market and systemic failures related to the specific features of knowledge production, firms tend to underinvest in innovation. The results of this research suggest that enabling firms to scale-up, expand exports, and engage in co-operation in innovation activities could incentivise investment in innovation. In addition, improving access to external finance could increase the propensity of firms to invest in innovation, in particular in R&D which is known to be uncertain and risky.

Further research on how access to finance and other factors impact on firms' decisions to invest in innovation could provide useful evidence. In this context, it would be also useful to assess the impact of direct and indirect enterprise supports such as R&D grants and R&D tax credits on firms' investment in R&D and their innovation, productivity and export performance. Another research avenue worth pursuing is an examination of the complementarity or substitutability of investment in R&D and in non-R&D assets and how these affect firm outcomes.

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Table A1: The share of firms with innovation expenditure in all firms by ownership and export participation

	2006	2008	2010	2012	2006	2008	2010	2012	2006	2008	2010	2012
	Non-exporter				Exporter				All firms			
	Irish-owned											
Firms with R&D expenditure (in-house & external)	14.9%	14.7%	18.7%	21.9%	42.5%	42.8%	40.8%	50.3%	29.4%	27.4%	30.4%	37.5%
Firms with non-R&D expenditure	16.7%	17.9%	14.3%	9.1%	12.4%	15.4%	15.9%	6.2%	14.4%	16.7%	15.1%	7.5%
Firms with innovation expenditure	**31.6%**	**32.6%**	**32.9%**	**31.0%**	**54.9%**	**58.1%**	**56.8%**	**56.5%**	**43.8%**	**44.1%**	**45.5%**	**44.9%**
Firms with no innovation expenditure	68.4%	67.4%	67.1%	69.1%	45.1%	41.9%	43.2%	43.6%	56.2%	55.9%	54.5%	55.0%
	Foreign-owned											
Firms with R&D expenditure (in-house & external)	13.9%	19.9%	22.0%	24.9%	47.6%	42.0%	46.9%	51.4%	39.5%	36.0%	40.4%	44.0%
Firms with non-R&D expenditure	20.2%	8.2%	11.0%	8.8%	17.4%	14.1%	14.5%	11.3%	18.1%	12.5%	13.6%	10.6%
Firms with innovation expenditure	**34.1%**	**28.1%**	**33.0%**	**33.6%**	**65.0%**	**56.2%**	**61.4%**	**62.7%**	**57.5%**	**48.5%**	**54.0%**	**54.6%**
Firms with no innovation expenditure	65.9%	71.9%	66.5%	66.4%	35.2%	43.8%	38.8%	37.3%	42.5%	51.4%	46.0%	45.4%
	All firms											
Firms with R&D expenditure (in-house & external)	14.7%	15.5%	19.3%	22.4%	44.1%	42.5%	43.0%	50.6%	31.9%	29.7%	33.2%	39.5%
Firms with non-R&D expenditure	17.2%	16.4%	13.8%	9.0%	14.1%	14.9%	15.4%	8.1%	15.3%	15.6%	14.7%	8.4%
Firms with innovation expenditure	**31.9%**	**31.8%**	**33.0%**	**31.5%**	**58.1%**	**57.4%**	**58.4%**	**58.7%**	**47.2%**	**45.3%**	**47.9%**	**47.9%**
Firms with no innovation expenditure	68.1%	68.2%	67.1%	68.5%	41.9%	42.6%	41.6%	41.3%	52.8%	54.7%	52.0%	52.1%

Source: Authors' calculations based on linked micro-data from the CIS, CIP and ASI data sets. The data is weighted using firm-level weights based on grossing factors for the number of firms provided by the CSO.

Table A2: The share of firms with innovation expenditure in all firms by ownership and size class

	2006	2008	2010	2012	2006	2008	2010	2012	2006	2008	2010	2012	2006	2008	2010	2012
	Irish-owned															
	Small				Medium				Large				All firms			
Firms with R&D expenditure (in-house & external)	24.4%	23.3%	24.3%	31.5%	35.9%	34.2%	40.9%	48.2%	56.5%	49.0%	50.0%	45.1%	29.4%	27.4%	30.4%	37.5%
Firms with non-R&D expenditure	12.0%	17.0%	15.9%	7.7%	19.5%	16.5%	13.5%	6.9%	14.1%	14.4%	15.4%	8.5%	14.4%	16.7%	15.1%	7.5%
Firms with innovation expenditure	**36.5%**	**40.3%**	**40.1%**	**39.2%**	**55.4%**	**50.7%**	**54.4%**	**55.1%**	**70.7%**	**63.5%**	**65.4%**	**53.7%**	**43.8%**	**44.1%**	**45.5%**	**44.9%**
Firms with no innovation expenditure	63.5%	59.7%	59.7%	60.8%	44.6%	49.5%	49.5%	44.9%	29.3%	36.5%	36.5%	46.3%	56.2%	55.9%	55.9%	55.0%
	Foreign-owned															
Firms with R&D expenditure (in-house & external)	22.6%	19.8%	26.8%	29.7%	41.1%	38.0%	40.1%	44.9%	64.4%	67.4%	71.6%	70.4%	39.5%	36.0%	40.4%	44.0%
Firms with non-R&D expenditure	20.0%	13.7%	13.2%	6.6%	18.1%	12.3%	14.3%	14.8%	14.1%	10.4%	11.2%	6.7%	18.1%	12.5%	13.6%	10.6%
Firms with innovation expenditure	**42.6%**	**33.5%**	**40.1%**	**36.3%**	**59.2%**	**50.3%**	**54.3%**	**59.6%**	**78.5%**	**77.8%**	**82.8%**	**77.0%**	**57.5%**	**48.5%**	**54.0%**	**54.6%**
Firms with no innovation expenditure	57.0%	66.5%	66.5%	63.4%	41.1%	49.8%	49.8%	40.4%	21.5%	22.2%	22.2%	23.0%	42.5%	51.4%	51.4%	45.4%
	All firms															
Firms with R&D expenditure (in-house & external)	24.2%	22.7%	24.7%	31.1%	37.7%	35.7%	40.6%	46.9%	61.2%	59.4%	62.9%	60.4%	31.9%	29.7%	33.2%	39.5%
Firms with non-R&D expenditure	13.2%	16.4%	15.4%	7.5%	19.0%	14.8%	13.8%	10.0%	14.5%	12.1%	13.4%	7.4%	15.3%	15.6%	14.7%	8.4%
Firms with innovation expenditure	**37.4%**	**39.2%**	**40.1%**	**38.6%**	**56.7%**	**50.5%**	**54.4%**	**56.9%**	**75.8%**	**71.5%**	**76.3%**	**67.7%**	**47.2%**	**45.3%**	**47.9%**	**47.9%**
Firms with no innovation expenditure	62.7%	60.8%	60.8%	61.3%	43.3%	49.5%	49.5%	43.1%	24.7%	28.5%	28.5%	31.8%	52.8%	54.7%	54.7%	52.1%

Source: Authors' calculations based on linked micro-data from the CIS, CIP and ASI data sets. The data is weighted using firm-level weights based on grossing factors for the number of firms provided by the CSO.

Table B1: Description of Variables – Linked CIS/CIP/ASI data

Model stage	Variable	Type of variable	Description	Data Source
Propensity to invest in innovation and intensity of investment	Pr. (R&D)	Dependent variable - selection equation	A binary indicator taking value 1 if the firm reported positive expenditure on internal R&D and/or external (purchased) R&D during the survey year. Over the survey period (the survey year and the two preceding years), and 0 otherwise.	CIS data, 2006-2012
	R&D/Employee	Dependent variable - intensity equation	The amount spent on internal and/or external R&D per employee, during the survey year.	CIS data, 2006-2012.
	Pr. (Non-R&D)	Dependent variable - selection equation	A binary indicator taking value 1 if the firm reported positive expenditure on non-R&D innovation activities over the survey period (acquisition of machinery, equipment, software buildings and other), and 0 otherwise.	CIS data, 2006-2012
	Non-R&D/Employee	Dependent variable - intensity equation	The amount spent on non-R&D innovation activities (acquisition of machinery, equipment, software buildings and other) per employee, during the survey year.	CIS data, 2006-2012
	Pr. (Inn. Exp.)	Dependent variable - selection equation	A binary indicator taking value 1 if the firm reported positive expenditure on either R&D or non-R&D innovation activities over the survey period, and 0 otherwise.	CIS data, 2006-2012
	Total Inn. Exp./Empl.	Dependent variable - intensity equation	The amount spent on innovation activities (R&D and/or non-R&D) per employee, during the survey year.	CIS data, 2006-2012
	Foreign ownership	Independent variable	A binary variable identifying whether the firm has a domestic or foreign headquarter.	CIS data, 2006-2012
	Export Intensity	Independent variable	The fraction of turnover from exports in total firm turnover.	CIP and ASI data, 2005-2012
	Wage per employee	Independent variable	The value of expenditure on wages reported by a firm, divided by the number of employees	CIP and ASI data, 2005-2012
	Market Share	Independent variable	The ratio of a firm's (grossed) turnover over the total NACE 2-dig. sector (grossed) turnover, in each year.	CIP and ASI data, 2005-2012
	Average perceived internal financial constraint (3-digit industry)	Independent variable	The 3-dig. sector level average of the qualitative indicator (0, 1, 2, 3) representing firms' perceived constraint to innovation arising from lack of internal funds.	CIS data, 2006-2010
	Average perceived external financial constraint (3-digit industry)	Independent variable	The 3-dig. Industry level average of the qualitative indicator (0, 1, 2, 3) representing firms' perceived constraint to innovation arising from lack of external funds.	CIS data, 2006-2010
	Average perceived market risk (3-digit industry)	Independent variable	The 3-dig. Industry level average of the qualitative indicator (0, 1, 2, 3) representing firms' perceived constraint to innovation arising from uncertain demand.	CIS data, 2006-2010
	Value Added per Employee	Independent variable	The value of sales, net of the cost of materials and services, divided by the	CIP and ASI data,

			number of employees.	2005-2012
	Age	Independent variable	The number of years a firm has been active, since it was first surveyed in the CIP or the ASI questionnaires. Gap years are counted towards the total age.	CIP and ASI data, 1991-2012
	Employees	Independent variable	The number of employees reported by a firm.	CIP and ASI data, 2006-2012
	Cooperation	Independent variable	A binary indicator taking value 1 if the firm reported to have cooperated with other enterprises or institutions on its innovation activities.	CIS data, 2006-2012
Knowledge production - innovation output	Product Innovation	Dependent variable	A binary indicator taking value 1 if the firm reports to have introduced a new product over the survey period (survey year and preceding 2 years).	CIS data, 2006-2012
	Process Innovation	Dependent variable	A binary indicator taking value 1 if the firm reports to have introduced a process innovation over the survey period (survey year and preceding 2 years).	CIS data, 2006-2012
	Organizational Innovation	Dependent variable	A binary indicator taking value 1 if the firm reports to have introduced an organizational innovation over the survey period (survey year and preceding 2 years).	CIS data, 2006-2012
	Predicted R&D per employee	Independent variable	The predicted amount of R&D (internal and external) expenditure per employee from the 1st stage	1st stage of model output
	Predicted Non-R&D per employee	Independent variable	The predicted amount of non-R&D expenditure per employee from the 1st stage	1st stage of model
	Predicted Innovation Expenditure per employee	Independent variable	The predicted amount of total innovation expenditure per employee from the 1st stage	1st stage of model output
	Import intensity	Independent variable	The ratio of purchases from abroad over total firm turnover	CIP and ASI data, 2005-2012
	Tangibles per Employee	Independent variable	The value of investment in tangible capital, obtained by subtracting the investment in intangibles from the total investment, divided by the number of employees.	CIP and ASI data, 2006-2012
	Perceived internal financial constraints	Independent variable	A binary indicator taking value 1 if the firm reports constraints to innovation arising from lack of internal funds.	CIS data, 2006-2010
	Perceived external financial constraints	Independent variable	A binary indicator taking value 1 if the firm reports constraints to innovation arising from lack of external funds.	CIS data, 2006-2010
	Perceived market risk	Independent variable	A binary indicator taking value 1 if the firm reports constraints to innovation arising from uncertain demand.	CIS data, 2006-2010
Productivity	Value added per employee	Dependent variable	The value of sales, net of the cost of materials and services, divided by the number of employees.	CIP and ASI data, 2006-2012
	Predicted probability of product Innovation	Independent variable	The predicted probability that a firm reports to have introduced a new product over the survey period (survey year and preceding two years).	2nd stage of model output
	Predicted	Independent variable	The predicted probability that a firms	2nd stage

	probability of process Innovation		reports to have introduced a new process over the survey period (survey year and preceding two years).	of model output
	Predicted probability of organizational innovation	Independent variable	The predicted probability that a firm reports to have introduced an organizational innovation over the survey period (survey year and preceding two years).	2nd stage of model output
	Exporter	Independent variable	A binary variable identifying whether the firm reported sales from exporting.	CIP and ASI data, 2006-2012
	Importer	Independent variable	A binary variable identifying whether the firm reported to have imported goods and services.	CIP and ASI data, 2006-2012

Notes: All monetary variables are deflated by the 2-digit NACE producer price index (CIP data) or the Consumer Price Index (ASI data), with base year 2010. Variables entering more than one stage are described only once.

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