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The Impact of Investment in Knowledge-Based Capital on Productivity: Firm-Level Evidence from Ireland

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Abstract: This paper examines the impact of investment in knowledge-based capital on firm productivity. The analysis is based on a dynamic econometric model estimated with micro-data from Ireland over the period 2006-2012. We use broad measures of investment in knowledge-based capital which include expenditures on R&D, and on non-R&D intangible assets such as computer software, copyrights, patents and licences, royalties and organisational capital. The results indicate that on average, over and above other factors, an increase in investment in knowledge-based capital of 10 per cent increases firm productivity by 2 per cent. The research results indicate that productivity gains linked to investment in KBC are larger for Irish-owned firms in comparison to foreign-owned firms. Further, the estimates indicate that firms' productivity is more responsive to investment in R&D than to investment in non-R&D intangible assets.

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1 Introduction

In recent years there has been an increased focus on investment in knowledge-based capital (KBC) as a source of innovation and productivity growth. In this context, it is widely recognised that innovation-based growth is underpinned by investments in a broader range of intangible assets beyond R&D spending such as computer software and data sets, organisational know-how, human capital, designs and other forms of intellectual property (Andrews and de Serres 2012). This approach has been driven by the rapid growth of information and communication technologies (ICT) in the 1990s as a new general purpose technology and the need to understand complementary investments such as investment in skills and organisational change required to exploit the opportunities that ICT offered.[1]

Given their intangible nature, measuring investment in KBC assets and their impacts is challenging. Progress has been made following contributions from researchers and the OECD. The mostly used methodological framework is the one proposed by Corrado, Hulten and Sichel (2005, 2009) known as the CHS framework. The CHS framework has been developed initially as a macroeconomic approach using available data for the US. It provides a consistent conceptual framework for measuring three types of KBC assets: (i) c*omputerised information*: knowledge codified in computer programmes and computerised datasets; (ii) *innovative property*: R&D and knowledge assets that are protected through intellectual property (IP) rights such as patents, designs, copyrights and trademarks; and (iii) e*conomic competencies*: knowledge embedded in a firm's human and structural resources such as firm-specific training, organisational capital, and brand equity.

The CHS framework has been used to produce comparable data on investment in KBC across industries and countries. Existing evidence based on these harmonised data sets indicates that investments in KBC are sizeable and they have increased over time (Corrado et al. 2013, 2016; OECD 2013). In recent years, in a number of advanced economies, notably the US, the UK, and Sweden private business investments in KBC have been larger than investment in tangible (physical) capital (Corrado, Hulten and Sichel 2009; Dal Borgo et al. 2012; Corrado et al. 2016). Another common feature across advanced economies is the large and growing share of investment in non-R&D assets.

Recent studies using a growth accounting methodology have estimated that investment in intangibles[2] is an important source of productivity growth (Corrado et al. 2012, 2014; 2016; Dal Borgo et al. 2013; Niebel, O'Mahony and Saam 2017). Corrado et al. (2016) estimated that over the period 2000-2013, the contribution of intangible capital deepening to the annual labour productivity

[1] Karlsson et al. (2010) reviews the international evidence on the role of ICT as a new general purpose technology and complementary investments needed to exploit the growth opportunities ICT offer.

[2] Throughout this paper we use the terms knowledge-based capital (KBC) and intangible assets interchangeably.

growth was 0.6 per cent in the US and 0.3 per cent in 18 EU countries[3] included in the analysis. Dal Borgo et al. (2013) find that in the UK, intangible capital accounted for 23 per cent of the labour productivity growth over 2000-2008. Niebel, O'Mahony and Saam (2017) estimated that the output elasticity to intangibles over 1997-2007 ranged between 0.1 and 0.2 across ten EU countries. They also find that the contribution of intangibles to labour productivity growth tends to be highest in manufacturing and the financial sector.

Although measuring investment in KBC at the aggregate industry and macroeconomic levels has been progressed in recent years, measures of investment at the firm level are being built by using the currently reported information on R&D and non-R&D capitalised and current expenditures on intangible assets. Most existing firm-level analyses have focused on the impact of R&D expenditures and more broadly innovation expenditures on innovation and productivity growth.[4] To the best of our knowledge, firm level evidence on the impact of investment in KBC on productivity is very limited. Only a small number of studies have distinguished and quantified investment in other KBC assets beyond R&D, such as, economic competencies including human capital, brand equity and organisational capital. These studies analyse intangible investments and their effects on productivity in large economies such as the UK, Germany and Spain.

Riley and Robinson (2011) examine the relationship between intangible assets and firm productivity in the UK using linked employee and employer data for the period 1998-2006. Their analysis focuses on intangible assets produced within the firm and embedded in knowledge workers: organisational workers (managers and marketing related occupations), measuring economic competencies; R&D workers, measuring innovative property; and IT workers, measuring digitised information. The results of their analysis indicate a positive and significant link between these KBC assets and productivity. However, the identified effects are different for the various KBC assets examined, with organisational capital having a greater impact than R&D or IT capital.

Using the CSH conceptual framework for measuring investment in KBC, Crass and Peters (2014) examine the effects of investment in a comprehensive range of KBC assets on firm productivity in Germany over the period 2006-2010. The evidence indicates strong positive links between productivity and investment in R&D, brand equity[5] and firm-specific human capital. Their analysis also uncovers a long-term positive productivity effect following investment in innovative capital and branding equity. One innovative contribution of this paper is the evidence on complementary effects

[3] Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Portugal, Slovakia, Slovenia, Spain, Sweden, the United Kingdom.

[4] Recent evidence is reviewed by Hall (2011).

[5] Brand equity includes expenditures on market research and advertising.

from investing in various types of KBC assets. Such complementarities were found for investment in R&D and the patent stock; investments in innovative capital and firm-specific human capital; and for investments in innovative capital and brand equity.

Higón, Gómez, and Vargas (2017) estimate the effects of investments in R&D, advertising and human capital on total factor productivity in Spanish manufacturing firms. They find evidence of complementarities between investments in R&D and advertising, and between investment in advertising and human capital. Further, they find no conclusive evidence for the case of investments in R&D and human capital.

This paper examines the effects of investment in KBC on productivity of firms based in Ireland. More specifically, we use a panel of annual micro-data from Ireland over the period 2006-2012 and estimate a dynamic econometric model which links firm productivity to investment in R&D and in other knowledge-based assets including software, copyrights, patents, licences, and organisational capital. The novelty of our contribution is threefold. First, since it has been documented that the productivity performance of a firm is likely to be persistent (Bartelsman and Dhrymes 1998, Raymond at al., 2015), we use a dynamic model which accounts for the persistence and path-dependency of productivity when estimating its relationship with investment in KBC. Second, in addition to average effects, we account for heterogeneity in the key relationships and allow the effects of investment in KBC on productivity to differ across sectors (manufacturing and services; knowledge-intensive[6] and non-knowledge intensive industries) and across different groups of firms (Irish-owned and foreign-owned; small, medium-sized and large). Third, in contrast with existing evidence from large economies, we provide firm-level evidence from a small open economy, Ireland, with a high productivity multinational sector which allows us to examine the different behaviour of foreign-owned[7] and indigenous firms with respect to investment in KBC.

The key results indicate that on average, over and above other factors, investment in knowledge-based capital is positively linked to firm productivity. Over the analysed period, an increase in investment in knowledge-based capital by 10 per cent increased firm productivity by 2 per cent. The effect is statistically stronger for foreign-owned firms but it is more sizeable for Irish-owned firms. Further, we find the effect of investment in R&D on productivity is larger than the effect of investment in non-R&D knowledge assets.

[6] Table A1 in the Appendix identifies the knowledge-intensive industries following the Eurostat classification based on NACE Rev. 2. Business industries are classified as knowledge-intensive if the employed persons with tertiary education represent more than 33% in the total employment in that activity.

[7] The analysis of the behaviour and performance of foreign-owned firms relates to the activity of these firms reported in Ireland.

The remainder of this paper is structured as follows. Section 2 describes the data and measures of KBC at firm level used in the analysis. The next section explains the econometric methodology. Section 4 discusses the empirical results and section 5 summarises the main findings and discusses implications for the design of enterprise policies aiming to foster productivity growth and competitiveness.

2 Data and Descriptive Analysis

This analysis uses two data sets provided by Ireland's Central Statistics Office (CSO) the Census of Industrial Production (CIP) and the Annual Service Inquiry (ASI).

The CIP covers all firms having their whole or primary activity in industrial production (mining and quarrying; manufacturing; electricity, gas, steam, and air conditioning supply; water supply, sewerage, waste management and remediation activities) and having three or more persons engaged.[8] The information collected with the CIP survey includes location of ownership, turnover, employment and gross earnings, changes in capital assets, purchases of goods and services other than capital items. A more detailed questionnaire including information on changes in intangible assets, as well as exports and imports, is sent to firms with 20 and more persons engaged.

The ASI covers all firms having their whole or primary activity in the distribution and services sector (the retail, wholesale, transportation and storage, accommodation and food, information and communication, real estate, professional, scientific, technical, administrative and other selected services). The ASI is based on a census of firms with 20 and more persons and a stratified random sample for firms with less than 20 persons engaged. While all firms with 1 or more persons engaged are included in the survey frame, for firms with 1 person engaged, the data is imputed from administrative data sources.[9] The data collected with a more detailed questionnaire sent to firms with 20 or more persons engaged includes the variables of interest for this analysis collected with the CIP.

Given reporting requirements, the broadest coverage for data on intangible assets in the CIP and the ASI is for the period 2006-2012 (2012 being the last year for which the micro data research files are available). Taken together all data available from the CIP and ASI, our analysis is based on an unbalanced panel of annual data comprising 11,346 unique firms over the seven years period, which results in 38,647 firm-year observations. [10] All monetary variables used in the analysis are deflated

[8] According to the CSO, in 2012, the number of firms with three or more persons engaged having their whole or primary activity in industrial production was 4,580.

[9] The latest available information from the CSO indicates that about 18,000 firms were covered by the ASI.

[10] On average each firm appears 3.4 times in the analysed panel data. This average is due to some firms entering and exiting over the 2006-2012 period, either because of cessation of economic activity, or because of mergers and

by price indices available from the Central Statistics Office: the NACE 2 digit producer price indices for industrial sectors and the consumer price index for the remaining sectors.

Measuring investment in KBC

To construct measures of investment in KBC at firm level, we use the analytical CHS framework (Corrado et al. 2005, 2009) discussed in Section 1. The CHS approach is based on expenditures on own produced intangible assets and purchased knowledge services. Following this approach, we have first extracted information on firms' own account investment in knowledge-based capital assets, available from the CIP and the ASI surveys: these are annual additions to capitalised R&D; software; copyrights, patents and licences for intellectual property; and other fixed intangible assets. Subsequently, in order to obtain a broader measure of investment in KBC to also include purchased knowledge services, we added annual expenditures on purchased R&D services; royalties on technical know-how; and expenditure on management and marketing fees as proxy for organisational capital. Finally, we have constructed measures of investments in KBC, by aggregating the capitalised and current expenditures for own account knowledge-based assets and purchased knowledge services as follows:

- *investment in R&D*: annual capitalised R&D expenditure and expenditures for purchased R&D services;
- *investment in software*: annual capitalised expenditures for computer software;
- *investment in organisational capital*: expenditures on management and marketing fees;
- *investment in intellectual property*: annual capitalised expenditures on copyrights, patents and licenses and expenditures on royalties on technical know-how;
- *investment in other intangibles*: capitalised expenditures on other intangible fixed assets;
- *investment in non-R&D*: investments in software, organisational capital, intellectual property and other intangibles;
- *total investment in intangibles*: investment in R&D, software, organisational capital, intellectual property and other intangible assets.

Other variables

The dependent variable in model specifications is labour productivity measured as value added per employee, i.e. the value of sales net of costs of materials and services divided by the number of employees[11]. Other regressors used in estimations include the value of investment in tangible capital

acquisitions. Other reasons could include changes in employment with downsized firms with less than 20 employees not being included in the more detailed surveys.

[11] Given that information on physical output is not available, the productivity is measured on the basis of real value added. This implies that the productivity measure, particularly in the case of foreign-owned firms may be distorted by transfer

assets (per employee), the amount spent on wages (per employee), the age of the firm and a binary variable indicating whether a firm is Irish or foreign-owned. Details of all variables and data sources are given in Table A1 in the Appendix.

Descriptive statistics

Following on from previous firm-level evidence on investment in innovation,[12] firms' decisions related to investment in KBC are likely to be influenced by their ownership status (Irish or foreign-owned), their export activity and their size. Figures 1 and 2 show a yearly breakdown of the share of firms investing in R&D intangibles,[13] non-R&D intangibles[14], together with the remainder category of firms not investing in any kind of intangible asset, by various subgroups of firms. Tables A2 and A3 in the Appendix report the shares of firms investing in R&D, of firms investing in non-R&D by firm ownership and export participation and by ownership and size class.

The first noteworthy feature in Figure 1 is that, relative to the differences in the composition of investors and non-investors across the categories of firms, time variation is an issue of second order importance. Within the groups in which firms were divided, the shares of firms investing in R&D and non-R&D intangible assets are in fact rather stable over time.

Variation across different groups of firms is instead much more evident. The shares of firms investing in KBC are lower among Irish-owned firms in comparison to foreign-owned firms. This difference is mostly accounted for by non-exporters, a large group of firms with the lowest shares of investors in R&D. In contrast, Irish-owned exporters have the highest share of investors in R&D, even higher than foreign-owned firms, among which exporters tend to invest more in R&D than non-exporters. Overall, it appears that with respect to engagement in R&D investment, the largest gaps emerge between non-exporters and exporters, regardless of ownership.

Concerning non-R&D investment, ownership is the decisive factor in driving the gap between investors and non-investors: regardless of firms' engagement in the export market, the share of firms investing in non-R&D is higher among foreign-owned firms, relative to Irish-owned firms. Between non-exporters and exporters, the shares of non-R&D investors are roughly similar. Finally, it is noteworthy that the shares for all firms (shown as *Total* in Figure 1) are strongly dominated by

pricing. Since transfer pricing is not observed in the data, to endure that revenue distortions do not impact systematically the results of this analysis, the key regressions are run separately for Irish-owned and foreign-owned firms.

[12] This evidence has been obtained with analysis based on the CDM model. Recent reviews of this evidence include Mairesse and Mohnen (2010), Ruane and Siedschlag (2013), and Broström and Karlsson (2016). Siedschlag and Zhang (2015) provide evidence for Ireland.

[13] Firms reporting either investment in R&D capital assets, or expenditure in R&D services, or both.

[14] Firms investing and/or spending in any of the following: software, patents, copyrights and licenses, royalties on technical know-how, management fees and other intangibles.

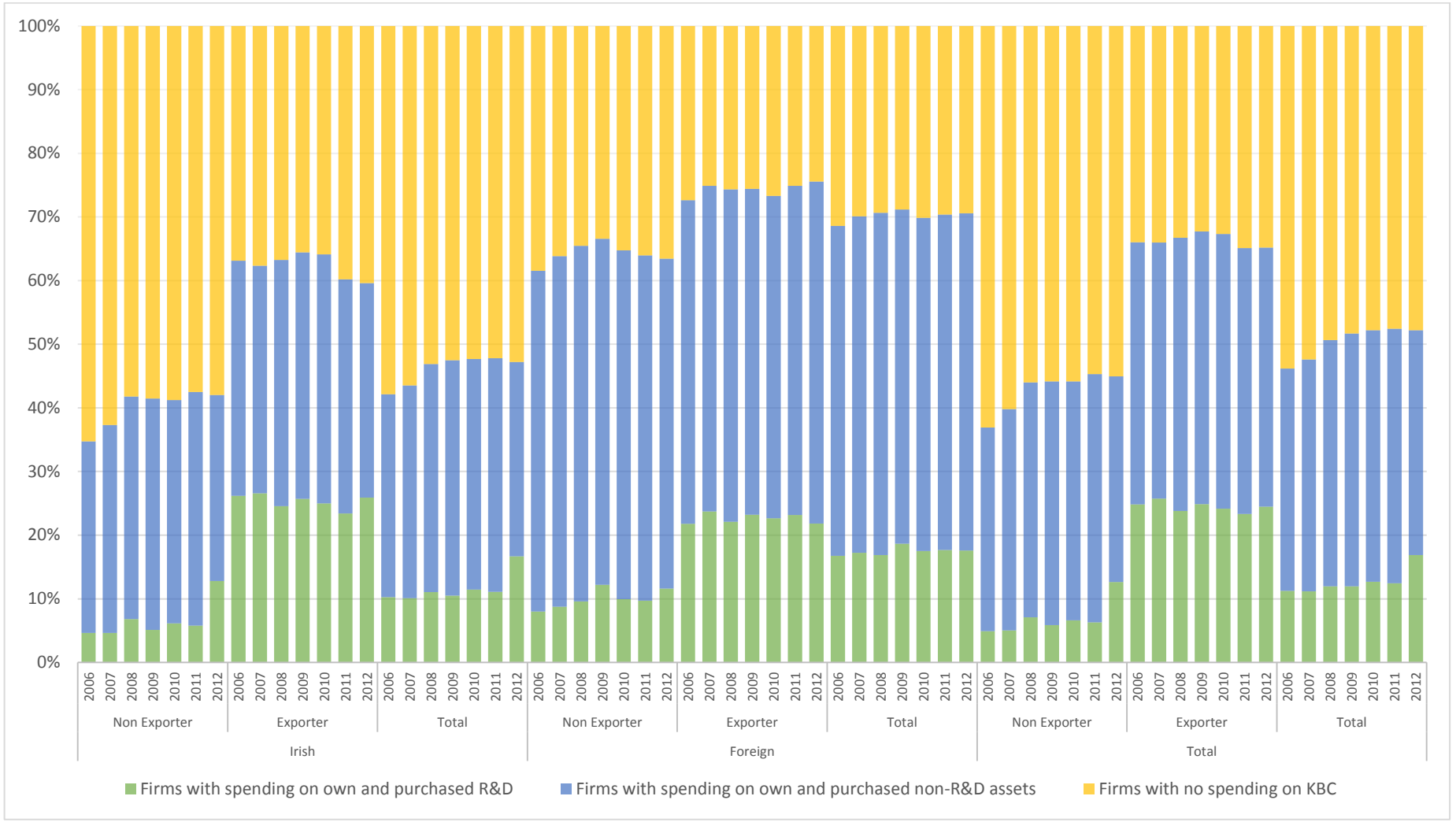
Irish-owned firms, which are much more numerous than foreign-owned firms in the analysed sample.[15]

Further distinctions across different firm groups can be drawn by splitting firms into three size classes: small firms (20 to 50 employees), medium-sized firms (50 to 250 employees), and large firms (250 and more employees). In Figure 2, where there is no distinction between non-exporters and exporters, the shares of investors in R&D are rather similar across the three size groups. Overall, relative to Irish-owned firms, foreign-owned firms have higher shares of R&D investors in all size categories. However, among large Irish-owned firms, the share of R&D investors are comparable to that of foreign-owned firms, although less so in the last three years of available data, 2010-2012.

Examining firms' engagement in non-R&D investment, it appears that the share of firms active in this category of intangibles grows as firm size grows. Again Irish-owned firms show lower shares of non-R&D investors than foreign-owned firms, except for the group of large firms, where the share of investors is comparable across the two ownership categories. In Figure 2, the time dimension appears to matter more than in Figure 1: in all size classes the share of investors grows slightly over time, especially among small and medium sized firms, both Irish and foreign-owned. This feature is mostly due to the growing shares of investors in non-R&D intangibles.

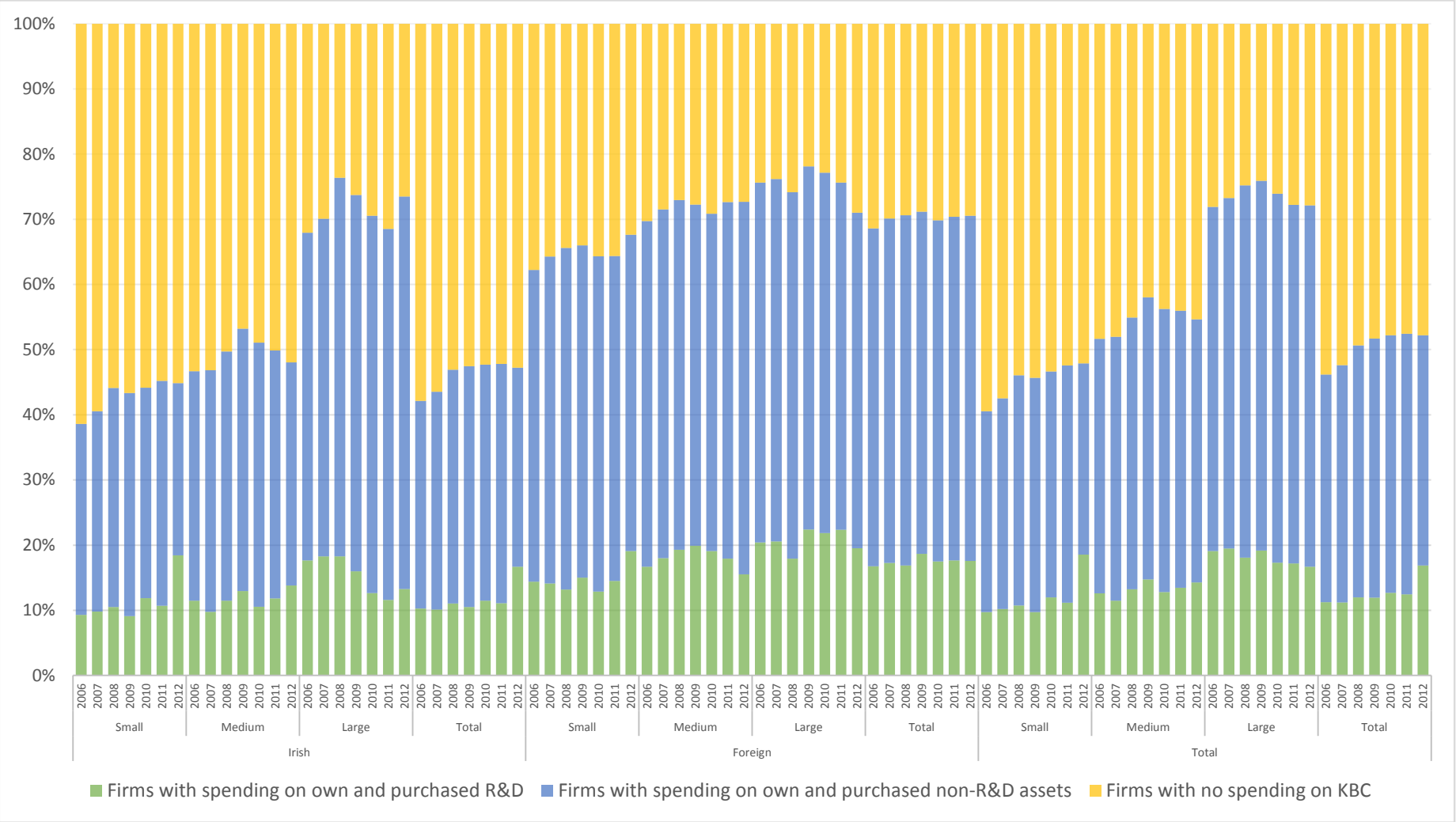
[15] Among the 11,346 firms analysed in this paper, 9,935 firms are Irish-owned compared with 1,817 foreign-owned firms.

Figure 1: The shares of firms investing in R&D and non-R&D, by ownership and export participation



Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

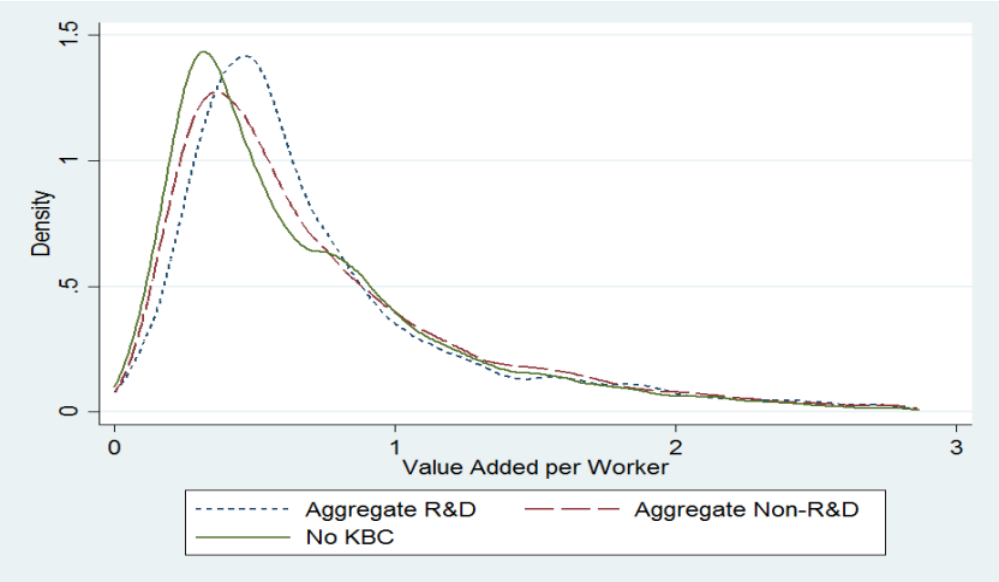
Figure 2: The shares of firms investing in R&D and non-R&D, by ownership and size class



Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

Figure 3 shows the productivity (log value added per employee) distributions of investors in R&D, investors in non-R&D knowledge-based assets and firms with no investments in KBC. The productivity distribution of firms investing in R&D dominates the distribution of non-investors, especially among lower productivity firms, suggesting a higher average productivity for R&D investors. This descriptive evidence is informative for the econometric analysis we undertake next.

Figure 3: Distribution of (log) productivity, by investment categories.



Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

Further heterogeneity among the sub-groups of Irish and foreign firms, exporters and non-exporters, emerges when analysing the intensity of investment in intangibles, measured as investment per employee.

Table 1: Intensity of investment in all KBC assets, 2006-2012

	Non-exporter	Exporter	Total	
Irish	4.68	9.92	6.58	Mean
	1.00	2.07	1.27	Median
	9,288	5,296	14,584	Firm-Year Observations
Foreign	76.75	145.44	119.72	Mean
	3.54	5.54	4.69	Median
	1,799	3,006	4,805	Firm-Year Observations
Total	16.37	58.99	34.62	Mean
	1.18	2.94	1.72	Median
	11,087	8,302	19,389	Firm-Year Observations

Notes: The summary statistics are obtained using only observations with positive investment values. The mean and median figures are in thousands Euros, per employee, in constant 2010 prices.
Source: Authors' calculations based on linked CIP and ASI data.

In Table 1 the strongest contrast emerges when comparing the mean investment intensity of Irish and foreign-owned firms, with the figures for the latter dominating by far the figures for the former. However, it is noteworthy that the gap between Irish and foreign-owned firms closes a great deal when the median intensity is compared, signalling the presence of some extremely large investment flows in the case of foreign-owned firms. The mean and median investment intensities are higher for exporters than non-exporters for both Irish and foreign firms. Again, the gaps are significantly larger for the means, especially among foreign-owned firms.

The patterns identified in Table 1, with foreign-owned firms and exporters investing a larger amount in KBC per employee than, respectively, indigenous firms and non-exporters, are confirmed when the full analysed sample is split between firms in industry and services. Tables A4 and A5 in the Appendix show these results.

Table 2 splits firms further into the three size groups, adding the size dimension to those of ownership and export status. Within each size group, the patterns identified in Table 1 are confirmed: foreign-owned firms invest more than Irish-owned firms, and exporters invest more than non-exporters. Only among large Irish-owned firms, the mean intensity of investment by non-exporters is larger than the corresponding figure for exporters.

Across size groups, without distinguishing between ownership and export status, both the average and the median for investment intensity are smallest for small firms, and highest for large ones. Some interesting heterogeneity is uncovered when looking more deeply into the various firm categories: for Irish firms, the mean for investment intensity increases when moving from small to large firms, while the median investment intensity is largest for medium-sized firms. This suggests the presence among medium-sized firms of a bigger number of firms with an investment intensity which is higher than that of large firms.

Inspecting the differences among foreign-owned firms of different sizes, it's interesting to notice that the mean investment intensity is highest for large firms, but with small firms investing on average more than medium-sized firms. If firms are instead ranked according to the median investment intensity, small foreign-owned firms report the highest intensity, with large and medium-sized firms coming next, although with values that are close to each other.

A final noticeable feature is that the overall mean and median figures are driven by the values measured for non-exporters when firms are Irish-owned, whereas for foreign-owned firms this is much less evident suggesting that the numbers of firms are more evenly distributed between exporters and non-exporters.

Table 2: Intensity of investment in KBC, all firms by size groups, 2006-2012

	Small firms (20<Empl.<50)			Medium firms (49<Empl.<250)			Large firms (Empl.>249)			Total			
	Non-Exporter	Exporter	Total	Non-Exporter	Exporter	Total	Non-Exporter	Exporter	Total	Non-Exporter	Exporter	Total	
Irish	3.76	6.2	4.54	5.27	15.3	9.47	12.49	9.27	10.97	4.68	9.92	6.58	Mean
	0.97	1.94	1.21	1.09	2.29	1.47	0.81	2.06	1.16	1	2.07	1.27	Median
	5,995	2,839	8,834	2,802	2,018	4,820	491	439	930	9,288	5,296	14,584	Firm-Year Observations
Foreign	94.04	124.7	111.89	71.22	100.97	90.36	58.69	264.57	192.7	76.75	145.44	119.72	Mean
	4.93	5.17	5.04	3.54	5.01	4.36	1.24	11.97	4.55	3.54	5.54	4.69	Median
	639	890	1,529	791	1,428	2,219	369	688	1,057	1,799	3,006	4,805	Firm-Year Observations
Total	12.45	34.48	20.38	19.79	50.8	34.97	32.31	165.12	107.64	16.37	58.99	34.62	Mean
	1.13	2.46	1.48	1.39	3.22	2.07	0.97	4.72	2.25	1.18	2.94	1.72	Median
	6,634	3,729	10,363	3,593	3,446	7,039	860	1,127	1,987	11,087	8,302	19,389	Firm-Year Observations

Notes: The summary statistics are obtained using only observations with positive investment values. The mean and median figures are in thousands Euros per employee, in constant 2010 prices.

Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

3 Econometric Methodology

To analyse the relationship between investment in KBC and firm productivity we estimate a dynamic econometric model which accounts for the persistence of firm productivity over time and its dependence on past performance. Persistent differences in productivity between firms have been shown to be widespread (Bartelsman and Doms, 2000; Raymond et al., 2015) and have been mostly attributed to firms' selection at entry (Hopenhayn 1992, Melitz 2003), demand channels[16] (Moreira 2016), learning-by-doing, innovative efforts and investment in higher quality managerial capital (Syverson, 2011). In assessing the productivity enhancements due to new investment in KBC, we therefore account for the self-perpetuating productivity process triggered by the innate skills embodied in firms at entry, demand factors and the intangible capital already accumulated by firms in the past. In this way, we obtain unbiased estimates of the relation between investment in KBC and productivity,[17] over and above the effect of the widely known drivers of productivity differences between firms.

For these reasons, in the estimation set up we link firm productivity to its productivity performance in the previous year.[18] In addition, in order to obtain unbiased estimates, we control for other firm-level factors that are both related to productivity and investment in KBC. Finally, we exploit the panel nature of the data, which allows us to apply econometric techniques that accounts for any other unobserved time invariant factors which might affect productivity. Taken together all these factors, we estimate the following dynamic model:

$$\ln(VA/Empl_{ij,t}) = \beta_0 + \beta_1 \ln(VA/Empl_{ij,t-1}) + \beta_2 \ln(Intangibles/Empl_{ij,t}) + \beta_4 \ln(Tangibles/Empl_{ij,t}) + \beta_5 \ln(Wage/Empl)_{ij,t} + \beta_5 \ln(Age)_{ij,t} + \beta_5 \ln(Foreign)_{ij,t} + \delta_t + \sigma_i + \rho_j + \mu_{ijt}$$

The dependent variable, firm productivity, is measured as the value-added per employee $\mathrm{Ln}\left(VA/Empl_{ij,t}\right)$, taken in its natural logarithm. Value added is calculated as the value of sales net of the cost of materials and services. The lagged value of the dependent variable accounts for the dynamic process driving firm productivity. The main explanatory variable of interest is investment in intangible assets, $\mathrm{Ln}\left(Intangibles/Empl_{ij,t}\right)$, whose association with productivity is identified by the parameter β_2. The other explanatory variables, i.e. tangibles per employee, wage per employee, the age of the firm and the foreign ownership indicator, are included in the analysis because they are related to both productivity and investment in intangibles.

[16] Demand accumulation through consumer reputation and brand awareness.

[17] Especially because investment in KBC is likely to be correlated with past firm productivity.

[18] Controlling for past productivity over two periods instead of one leaves the results unchanged; furthermore the second lagged period turns out to be often insignificant. These estimates are shown in Table A8 in the Appendix.

The remaining variables are a set of controls which pick up any unobservable time constant factor affecting firm's productivity (σ_i), any shock which is common across all firms in a given year (δ_t), and any shock which is common across all firms in a NACE 2-digit sector (ρ_j), which might otherwise affect firm productivity.

The dynamic-panel setting applied to the available data, with a short time dimension (at most 7 years) relative to the number of cross-sectional units, requires instrumenting the lagged dependent variable $\mathrm{Ln}(VA/Empl_{ij,t-1})$ to circumvent the correlation of this regressor with the residual of the model (Nickel, 1981). For this purpose, we apply the Arellano-Bond (1991) methodology in a generalized method of moments (GMM) econometric framework, exploiting further lags of the dependent variable to instrument $\mathrm{Ln}(VA/Empl_{ij,t-1})$.

A GMM procedure offers a variety of estimation options. To motivate the choice of the estimator, in Table 3 below we compare results from a pooled-OLS model (POLS), a fixed-effects within estimator (FE) and a system-GMM estimator (Blundell and Bond, 1998). The coefficient on the lagged dependent variable is indicative of the correct specification of the GMM model. Both the POLS and the FE estimators are biased, but they can be taken as, respectively, an upper and a lower bound estimate of the lagged dependent variable coefficient. Arellano and Bond (2001) suggest that the GMM estimate should lie in between the POLS and the FE estimates: this "rule-of-thumb" holds in Table 3 suggesting that the system-GMM estimator is the appropriate one.[19]

The system GMM jointly estimates the dynamic model both in differences and in levels,[20] using lagged levels as instruments for the regression in differences and lagged differences as instruments for the regression in levels. In this paper, we present results that rely on lagged levels dated from t-2 to t-4 for the regression in differences and lagged differences dated t-1 for the regressions in levels.[21] The exogeneity of the lags exploited in the instrumentation is confirmed by the Arellano-Bond test for serial autocorrelation, which fails to reject the null of no first-order correlation in the residuals[22]. In addition, we report the Hansen J-test of the null hypothesis that the over-identifying

[19] This is visible from the lagged dependent variable coefficient and the p-values for the Hansen-J test statistic, whose range indicate that the instruments are valid and not affected by a weak instrumentation issue.

[20] Estimating the model in both differences and levels addresses the weak instrument problem arising from using lagged-levels of persistent explanatory variables as instruments for the regression in differences (Blundell and Bond,1998). However, a strong assumption of this approach is that changes in the instrumental variables are uncorrelated with the fixed effects.

[21] In the interest of space we report result with one set of lags used as instruments (the t-2, t-3 and t-4 lags in levels for the differences regressions and the t-1 lag in differences for the level regressions); however, we estimated all regressions in this analysis exploiting all the possible combinations of lags (starting from t-2 and ending at t-6), in order to reassure about the robustness of the system-GMM estimates. The results are extremely similar across all lags specifications and are available on request from the authors.

[22] This implies that lags starting at t-2 are uncorrelated with the residual and are valid instruments for the lagged dependent variable.

restrictions are valid: here we always fail to reject the null hypothesis, confirming the validity of the instrumentation procedure.Finally, the GMM instrumentation procedure can help to instrument additional regressors which are likely to exhibit a correlation with the residual of the model, other than the lagged dependent variable. In this context, it could be argued that investment in intangibles is determined simultaneously with firm productivity, causing a reverse causality bias. Similarly, also the value of investment in tangibles and the average wage per employee are likely to be endogenous to productivity due to a simultaneity issue. To circumvent these endogeneity concerns we instrument investment in intangibles, investment in tangibles and the wage per employee with their past values, exploiting the same lag structure exposed for the instrumentation of the lagged dependent variable.

4 Empirical Results

Investment in aggregate intangible assets and firm productivity

Table 3 reports the estimates of the dynamic model outlined above using the system-GMM estimators as discussed in Section 3.

As expected, the past value of firm productivity is a positive and significant determinant of current firm productivity. This is found consistently across all the specifications estimated and the firm subgroups analysed. Persistence is rather high, with a 10 per cent higher productivity reflected in a 6 per cent higher productivity in the next time period. On average, investing in KBC affects firm productivity positively and significantly: an increase in investment in KBC per employee by 10 per cent translates to a 1.8 per cent higher productivity. This result, statistically very robust and economically sizeable, is found when all firms are analysed.

However, as shown in Table 3, important heterogeneity exists across various groups of firms. Investing in KBC affects firms' productivity to a larger extent in the case of Irish firms than for foreign firms, although the estimate is much more precise (its statistical significance much higher) on the subsample of foreign-owned firms. This suggests that the performance of foreign-owned firms drives the link between investment in KBC and productivity obtained for all firms. The estimated coefficient in column (3) is in fact close to that of foreign-owned firms.

Contrasting manufacturing and service firms, we find that investing in KBC positively affects the productivity for both types of firms, but the effect is more than three times larger for manufacturing firms relative to service firms. Investing in intangibles is also positively linked to the productivity of firms in non-knowledge-intensive industries, but has only a weak impact on the productivity of firms in the knowledge-intensive industries. This result could be linked to the fact that factors other than investment in KBC are less important for the productivity of firms in industries which are not

knowledge-intensive. The last comparison is within the manufacturing sector, between firms in the food and non-food industries: while investment in KBC raises productivity for firms in the non-food industries, it appears to be even more important in the food industry, where the estimated coefficient is the largest among all estimated effects.

With respect to other covariates, it appears that investment in tangible capital per employee does not have a significant effect on firms' productivity, over and above the impact of investment in KBC. A positive and sizeable association between tangibles and productivity is only found in food industries, but this result is too weak to be generalised. Wages per employee is used as a proxy for the skill intensity of the work force. When all firms are pooled together (column 3) no significant link is found with firm productivity, but this result is probably driven by Irish-owned firms, for which the estimated effect is negative (albeit insignificant). For foreign-owned firms, productivity is strongly associated with the wage per employee, as well as in the subsamples of manufacturing firms, non-knowledge intensive firms and the non-food manufacturing firms. More mature Irish-owned firms, in knowledge-intensive and in food industries have a higher productivity, while in the other groups of firms analysed, age is not significantly related to firms' productivity. Finally, as expected, foreign-owned firms are on average more productive than Irish-owned firms, particularly in manufacturing industries.

Table 4 analyses the impact of investment in intangibles on productivity across different firms' size classes. Columns 1-4 show the results obtained aggregating Irish and foreign-owned firms, whereas columns 5-8 show the results for Irish-owned firms only.

Investment in KBC increases productivity in small and medium-sized firms (firms with 20 to 250 employees). This positive effect is driven by medium-sized firms (firms with 50 to 250 employees). The effect for small firms is small but statistically significant, while the effect of investment in KBC on productivity is positive but not statistically significant for large firms. Restricting the analysis on the subgroup of Irish-owned firms (columns 5-8) changes this finding somewhat, because the association between intangibles and productivity is largest for small firms (firms with 20 to 50 employees), and statistically significant only for this size class. This result suggests a further difference between Irish and foreign-owned firms: the link between investment in KBC and productivity for foreign firms is strongest at a different (possibly higher) point along the size distribution compared to Irish firms.

Table 5 provides an additional disaggregation of the analysed firms based on export participation. Regardless of firm ownership, it appears that the association between aggregate investment in intangibles and productivity is larger for non-exporters than for exporters (columns 1 and 2); however, distinguishing among Irish and foreign firms, it is evident the result is driven by foreign-

owned non-exporting firms. In contrast, in the group of Irish firms, the results indicate that exporters gain more in terms of labour productivity from investing in KBC relative to non-exporters.

Table 3: Investment in intangibles and firm productivity – aggregate intangibles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep. Var.	**Ln (VA/Employee)**										
Estimator	**Pooled OLS**	**Fixed Effects**	**1 step System GMM**								
GMM lag structure			**(t-2, t-3, t-4)**								
Sample	All firms	All firms	All firms	**Irish**	**Foreign**	**Service**	**Manuf.**	**KII=0**	**KII=1**	**Non-Food Manuf.**	**Food**
Ln (VA/Employee)$_{t-1}$	0.816***	0.273***	0.637***	0.720***	0.611***	0.651***	0.495***	0.617***	0.740***	0.486***	0.621***
	(0.030)	(0.032)	(0.038)	(0.066)	(0.056)	(0.065)	(0.103)	(0.027)	(0.081)	(0.095)	(0.123)
Ln (Intang. /Empl.)	**0.124*** **	**0.191** **	**0.185** **	**0.363***	**0.240*** **	**0.119*** **	**0.388*** **	**0.341*** **	**0.114'**	**0.423*** **	**0.650** **
	(0.043)	**(0.078)**	**(0.077)**	**(0.206)**	**(0.044)**	**(0.045)**	**(0.099)**	**(0.066)**	**(0.074)**	**(0.132)**	**(0.301)**
Ln (Tang. /Empl.)	0.057***	0.033	0.023	-0.229***	0.120	-0.001	0.101	-0.078	-0.127	0.071	0.152'
	(0.015)	(0.028)	(0.086)	(0.087)	(0.095)	(0.099)	(0.145)	(0.098)	(0.205)	(0.173)	(0.098)
ln(Wage/Employee)	0.489***	1.293***	0.260	-0.487	0.859***	0.647'	0.546**	1.040***	0.799**	1.691***	0.169
	(0.052)	(0.076)	(0.308)	(0.479)	(0.307)	(0.420)	(0.259)	(0.240)	(0.335)	(0.398)	(0.166)
ln(Age)	0.007	0.027	0.016**	0.026***	0.023	0.012'	0.009	0.006	0.023**	0.000	0.025***
	(0.005)	(0.022)	(0.007)	(0.008)	(0.019)	(0.008)	(0.009)	(0.008)	(0.010)	(0.008)	(0.002)
Foreign-owned	0.009	0.088***	0.069***			0.022	0.098***	0.074***	0.047**	0.098***	-0.034
	(0.011)	(0.028)	(0.017)			(0.018)	(0.020)	(0.023)	(0.020)	(0.015)	(0.047)
Constant	-0.006	0.029**	-0.015'	-0.008	-0.026	-0.024'	-0.024**	-0.028***	-0.073**	-0.053***	-0.008
	(0.005)	(0.012)	(0.010)	(0.008)	(0.038)	(0.015)	(0.009)	(0.007)	(0.036)	(0.012)	(0.016)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N observations	25674	25674	25674	20729	4945	17336	7809	21474	4200	6086	1723
GMM instruments			72	71	71	72	72	72	72	72	72
P value AR2 test			0.735	0.526	0.888	0.864	0.695	0.596	0.106	0.888	0.439
P value Hansen test			0.522	0.513	0.827	1.000	1.000	0.928	1	1	1

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' calculations based on data from on CIP and ASI data.

Table 4: Investment in intangibles and firm productivity – aggregate intangibles, by size groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Ln (VA/Empl.)							
Estimator	1 step System GMM							
GMM lag structure	(t-2, t-3, t-4)							
Sample					Only Irish firms			
	SMEs	**Small**	**Medium**	**Large**	**SMEs**	**Small**	**Medium**	**Large**
ln(VA/Employee)$_{t-1}$	0.561***	0.508***	0.662***	0.707***	0.614***	0.536***	0.665***	0.836***
	(0.047)	(0.047)	(0.057)	(0.063)	(0.067)	(0.090)	(0.070)	(0.138)
Ln (Intang. /Empl.)	**0.235****	**0.139***	**0.213****	**0.088**	**0.542****	**0.530*****	**0.227**	**0.199**
	(0.096)	**(0.071)**	**(0.108)**	**(0.081)**	**(0.234)**	**(0.187)**	**(0.173)**	**(0.331)**
Ln (Tang. /Employee)	0.129	0.061	-0.070	-0.097	-0.241***	-0.286***	-0.101	-0.046
	(0.103)	(0.099)	(0.066)	(0.178)	(0.091)	(0.099)	(0.077)	(0.095)
Ln (Wage/Employee)	0.695*	1.187***	0.461	0.481	0.214	0.334	0.960**	-0.323
	(0.395)	(0.412)	(0.494)	(0.594)	(0.546)	(0.450)	(0.442)	(1.151)
ln(Age)	0.013**	0.009	0.013	0.006	0.015**	0.017**	-0.007	0.093'
	(0.006)	(0.008)	(0.010)	(0.024)	(0.007)	(0.008)	(0.009)	(0.060)
Foreign-owned	0.057**	0.084***	0.030	0.059**				
	(0.024)	(0.021)	(0.035)	(0.024)				
Constant	-0.024**	-0.034**	-0.029*	-0.033	-0.015*	-0.020**	-0.033**	-0.076***
	(0.010)	(0.016)	(0.015)	(0.040)	(0.008)	(0.009)	(0.014)	(0.025)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
N observations	23629	14560	9069	2045	19756	12966	6790	973
GMM instruments	72	72	72	72	71	71	71	71
P value AR2 test	0.723	0.412	0.681	0.555	0.696	0.725	0.898	0.495
P value Hansen test	0.353	0.572	0.752	0.883	0.509	0.509	0.787	0.932

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

Table 5: Investment in intangibles and firm productivity – aggregate intangibles, by export status

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	ln(VA/empl)					
Estimator	**1 step SYS GMM**					
GMM lag structure	**(t-2, t-3, t-4)**					
Sample	All firms		Irish Firms		Foreign firms	
	Non Exporters	Exporters	Non Exporters	Exporters	Non Exporters	Exporters
$\ln(VA/empl)_{t-1}$	0.603***	0.669***	0.770***	0.571***	0.513***	0.673***
	(0.061)	(0.047)	(0.071)	(0.117)	(0.104)	(0.074)
ln(Intangibles/empl)	**0.160***	**0.096***	**0.274***	**0.446****	**0.392***	**0.126*****
	(0.096)	**(0.055)**	**(0.158)**	**(0.178)**	**(0.205)**	**(0.044)**
ln(Tangibles/empl)	0.229	-0.170***	0.038	-0.216***	0.184	-0.095
	(0.237)	(0.063)	(0.191)	(0.081)	(0.193)	(0.134)
ln(Wage/empl)	0.428	0.647	-0.737*	0.211	0.332	1.361***
	(0.469)	(0.522)	(0.398)	(0.502)	(0.394)	(0.476)
ln(Age)	0.024***	-0.008	0.031***	0.007	0.091*	-0.026
	(0.008)	(0.015)	(0.007)	(0.011)	(0.053)	(0.028)
Foreign	0.053**	0.064***				
	(0.026)	(0.015)				
Constant	-0.027'	-0.035	-0.019*	0.021	0.087	-0.031
	(0.017)	(0.030)	(0.011)	(0.016)	(0.061)	(0.032)
Time dummies	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
N observations	16405	9269	14536	6193	1869	3076
GMM instruments	72	72	71	71	71	71
P value AR2 test	0.691	0.456	0.357	0.832	0.344	0.255
P value Hansen test	0.604	0.753	0.682	0.638	0.907	0.832

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01. Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data

Investment in specific KBC assets and firm productivity

This section examines the impact of investment in specific KBC assets on firm productivity and provides insights on one of the key contributions of this paper: we show that, besides the role of investment in R&D, investment in non-R&D assets also affects firm productivity. Specifically, we examine the differential impacts on productivity coming from investments in R&D, computer software, organisational capital, intellectual property (IP) assets (patents, copyrights, royalties, licences), and other intangible assets. Non-R&D intangibles have heterogenous effects and, across the various subgroups of producers, they are associated with productivity with varying degrees of statistical significance. The results are reported in Table 6.

Column 1 reports the estimates for all firms. The largest effect on productivity over and above productivity persistence and other factors appears to be investment in software: the aggregate result is very large and more than proportional (a 10 per cent increase in the amount invested in software is associated with a 13 per cent higher firm productivity). Surprisingly, this effect is insignificant when the analysis is restricted to Irish-owned firms only, and results appear to be driven entirely by foreign-owned firms. Looking at the other sub-samples, a positive effect from investment

in software on productivity is found: the coefficient is larger (but less significant) in services than in manufacturing, large and significant for non-knowledge intensive industries and insignificant for knowledge intensive industries. Within the manufacturing industries, investing in software has a positive effect on productivity only in non-food firms; for firms in food industries the association is negative.

Investing in R&D is positively associated with productivity, although the related coefficient is lower compared to that of software investment. It is noteworthy that for Irish-owned firms, for which investment in software has no impact on productivity, R&D investment is found to affect productivity the most, and in a statistically significant way. In contrast, investment in R&D has barely any impact on the productivity of foreign-owned firms over and above other intangible investments (investments in computer software, organisational capital and IP assets) and other factors which influence firm productivity (such as past productivity and skills intensity). Furthermore, investing in R&D leads to productivity gains in manufacturing, but not in services. In non-knowledge intensive industries the link between investment in R&D and productivity is larger than in knowledge-intensive industries. Finally, for firms in the food industries, investing in R&D is associated with a much larger effect on productivity (about 10 times larger) than in the case of firms operating in non-food industries.

Investment in organisational capital is also strongly associated with productivity gains. The estimated coefficient is lower than the coefficients obtained for investment in computer software and R&D, but it is very stable and statistically significant in all firm subgroups. Only among services firms, it appears that investing in organisational capital doesn't affect productivity in a statistically significant way, but the effect is not completely null.

Investing in IP assets comes next in importance, as far as firm productivity is concerned. There is a positive association estimated for this type of intangible investment, but this is mostly driven by the subsample of foreign firms. Looking at the sectoral disaggregation, the amount invested in IP assets is significantly associated with higher productivity in manufacturing industries, and especially in non-food producing sectors.

Finally, investment in other intangible assets (not classified in one of the above mentioned categories) has little explanatory power over and above investment in software, R&D, organisational capital and in IP assets. The coefficient for investment in other intangible assets is, in fact, always statistically insignificant.

Robustness checks of the results in Table 6 showing the effects of investment in specific KBC assets on productivity are provided in Table A6 in Appendix. Table A6 shows that introducing investments in specific KBC assets one by one leaves the results explained in this section unchanged, with the estimated effects varying only marginally in size[23].

Table 7 shows the estimates of the impact of investments in specific intangibles on productivity unpacked across the three size groups considered in Table 4. The results obtained with the sample of all firms are confirmed here, especially in columns 1-4, where both Irish and foreign-owned firms are used in the estimations.

The results indicate that investing in computer software is again associated with the largest productivity gain. The effect is the largest for medium-sized firms and virtually zero for small firms, although it is statistically significant only for large firms. It is noteworthy that none of the coefficients estimated for the subsamples of Irish firms (columns 5-8) is statistically significant, confirming the result shown in Table 6 (column 2), where the estimates are not disaggregated by size groups.

Further, we find that R&D investment is positively linked to the productivity of small and medium-sized enterprises, either taken together (results shown in column 1) or estimated separately (columns 2 and 3). No effect is instead found for the subsample of large firms. Interestingly, when restricting the sample to Irish-owned firms only, for small enterprises we uncover the largest impact of investment in R&D on productivity: a 10 per cent higher investment in R&D per employee is associated with a 12 per cent higher productivity.

Investment in organisational capital, for which a stable and positive effect on productivity is estimated for the various firms' subgroups (results shown in Table 6), shows a positive association also across the three size groups in Table 7: the coefficients are similar in size, but statistically significant only for small and large firms. Focusing on Irish firms only, all the impact of organisational capital can be ascribed to small firms, with coefficients close to zero and with no statistical significance on medium and large Irish enterprises.

The association between investment in IP assets and firms' productivity is less stable than the one found for the intangibles explained above: a positive and significant coefficient is estimated for SMEs, which is mostly due to the effect found in the medium-sized firms. For Irish firms, only large firms appear to benefit from investing in IP assets.

[23] This econometric approach mitigates concerns related to multicollinearity among the specific KBC assets, when these are included in the same regression simultaneously.

Table 6: Investment in intangibles and firm productivity – specific intangibles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable					**Ln (VA/Employee)**				
Estimator					**1 step System GMM**				
GMM lag structure					**(t-2, t-3, t-4)**				
Sample	All firms	**Irish**	**Foreign**	**Service**	**Manuf.**	**KII =0**	**KII =1**	**Non-food**	**Food**
Ln (VA/Employee)$_{t-1}$	0.635***	0.716***	0.646***	0.647***	0.509***	0.615***	0.648***	0.493***	0.627***
	(0.028)	(0.056)	(0.037)	(0.026)	(0.080)	(0.029)	(0.036)	(0.047)	(0.116)
Ln (R&D/Employee)	0.296*	0.544**	0.270'	0.164	0.277***	0.407**	0.218*	0.276***	2.924**
	(0.174)	(0.219)	(0.168)	(0.380)	(0.068)	(0.200)	(0.131)	(0.064)	(1.347)
Ln (Software/Employee)	1.304***	-0.206	0.979***	1.931*	0.890***	1.670**	0.852	0.884***	-6.577***
	(0.464)	(0.968)	(0.354)	(0.992)	(0.143)	(0.756)	(1.008)	(0.187)	(1.209)
Ln (Organiz. Capital/Employee)	0.201***	0.342**	0.252***	0.100'	0.276***	0.305***	0.223***	0.249***	0.438*
	(0.055)	(0.137)	(0.060)	(0.065)	(0.074)	(0.104)	(0.050)	(0.087)	(0.260)
Ln (IP Assets/Employee)	0.069'	0.070	0.080**	0.019	0.290***	0.135**	0.053	0.327***	-0.090
	(0.044)	(0.112)	(0.035)	(0.044)	(0.065)	(0.068)	(0.090)	(0.045)	(0.209)
Ln (Other Intangibles/Empl.)	0.100	0.251	0.054	0.057	0.127	0.204	0.137	0.056	0.402
	(0.160)	(0.297)	(0.108)	(0.121)	(0.095)	(0.488)	(0.171)	(0.112)	(0.454)
Ln (Tangibles/Employee)	0.032	-0.142*	0.073	0.031	-0.025	0.162**	-0.136	-0.080	0.183***
	(0.073)	(0.081)	(0.108)	(0.109)	(0.101)	(0.076)	(0.157)	(0.095)	(0.070)
Ln (Wage/Employee)	0.442	0.093	0.734*	0.922**	0.419*	0.519'	0.832***	0.515**	0.695***
	(0.374)	(0.393)	(0.407)	(0.382)	(0.217)	(0.320)	(0.263)	(0.240)	(0.072)
Ln (Age)	0.013**	0.016**	0.020	0.009	0.008	0.009*	0.024**	0.000	0.019***
	(0.005)	(0.007)	(0.018)	(0.007)	(0.009)	(0.006)	(0.010)	(0.007)	(0.002)
Foreign-owned	0.060***			0.005	0.110***	0.044**	0.044*	0.109***	0.030
	(0.020)			(0.020)	(0.021)	(0.019)	(0.023)	(0.017)	(0.040)
Constant	-0.021*	-0.011	-0.015	-0.035**	-0.011	-0.009	-0.072***	-0.013	-0.016**
	(0.011)	(0.010)	(0.041)	(0.016)	(0.009)	(0.009)	(0.018)	(0.011)	(0.007)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
N observations	25674	20729	4945	17336	7809	21474	4200	6086	1723
GMM instruments	140	139	139	140	140	140	140	140	140
P value AR2 test	0.665	0.502	0.788	0.944	0.572	0.856	0.105	1.000	0.223
P value Hansen test	1.000	1.000	1.000	1	1	1.000	1	1	1

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

Table 7: Investment in intangibles and firm productivity – specific intangibles, by size groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	**Ln (VA/Employee)**							
Estimator	**1 step System GMM**							
GMM lag structure	**(t-2, t-3, t-4)**							
					Irish firms only			
Sample	**SMEs**	**Small**	**Medium**	**Large**	**SMEs**	**Small**	**Medium**	**Large**
Ln (VA/Employee)$_{t-1}$	0.595***	0.602***	0.721***	0.693***	0.647***	0.577***	0.778***	0.865***
	(0.035)	(0.047)	(0.051)	(0.038)	(0.076)	(0.081)	(0.072)	(0.086)
Ln (R&D/Employee)	0.325**	0.217**	0.276**	0.005	0.126	1.224*	0.152	-0.743
	(0.129)	(0.089)	(0.115)	(0.212)	(0.312)	(0.700)	(0.246)	(0.723)
Ln (Software/Employee)	0.970'	0.043	2.179	0.830***	-0.437	-2.664'	1.452	-1.089
	(0.627)	(0.935)	(1.569)	(0.236)	(1.349)	(1.719)	(1.231)	(0.774)
Ln (Organiz. Cap. /Employee)	0.196**	0.286***	0.122	0.174***	0.448***	0.599***	0.094	0.036
	(0.087)	(0.086)	(0.095)	(0.053)	(0.109)	(0.104)	(0.112)	(0.126)
Ln (IP Assets/Employee)	0.168**	0.114	0.119**	-0.013	0.149	-0.038	0.068	0.474*
	(0.082)	(0.148)	(0.046)	(0.067)	(0.132)	(0.169)	(0.126)	(0.251)
Ln (Other Intangibles/Empl.)	0.083	0.119	0.087	0.307***	0.381'	0.463	0.217	0.045
	(0.096)	(0.122)	(0.144)	(0.069)	(0.257)	(0.573)	(0.209)	(0.311)
Ln (Tangibles/Employee)	0.086	0.081	-0.045	-0.214*	-0.156*	-0.219***	-0.081	0.038
	(0.081)	(0.064)	(0.074)	(0.125)	(0.080)	(0.061)	(0.098)	(0.083)
Ln (Wage/Employee)	0.736**	0.926***	0.131	1.083**	0.509	0.968**	0.581***	-0.097
	(0.373)	(0.259)	(0.293)	(0.432)	(0.399)	(0.396)	(0.220)	(0.581)
Ln (Age)	0.012**	0.011*	0.018*	-0.010	0.009	0.009	-0.003	0.070**
	(0.005)	(0.006)	(0.010)	(0.023)	(0.006)	(0.008)	(0.006)	(0.035)
Foreign-owned	0.047*	0.059***	0.040*	0.049*				
	(0.026)	(0.016)	(0.024)	(0.028)				
Constant	-0.023*	-0.025***	-0.022*	-0.057*	-0.023***	-0.031**	-0.027***	-0.015
	(0.013)	(0.009)	(0.013)	(0.031)	(0.009)	(0.014)	(0.008)	(0.038)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
N observations	23629	14560	9069	2045	19756	12966	6790	973
GMM instruments	140	140	140	140	139	139	139	139
P value AR2 test	0.828	0.478	0.539	0.547	0.688	0.565	0.791	0.363
P value Hansen test	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

Lastly, when all firms are considered, the impact of the other intangible investments appears to be statistically insignificant, with the exception of the subgroup of large firms.

Table 8 shows that specific KBC assets have heterogeneous effects also between exporters and non-exporters, with productivity of exporters being affected more than productivity of non-exporters.

On both the subsamples of Irish and foreign firms, R&D investment results to affect productivity of exporters, while it not statistically significant for non-exporters. Similarly, investment in software is associated with productivity gains only for the subgroup of firms that export; with the addition that no impact is detected for Irish firms. Higher organizational capital results associated with higher productivity on virtually all subsamples represented in Table 8, with the exception of Irish exporters, which is somewhat surprising. Lastly, investment in IP assets are found to affect productivity of exporting firms only, and only if with Irish ownership.

Table 8: Investment in intangibles and firm productivity – specific intangibles, by export status

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	ln(VA/empl)					
Estimator	**1 step SYS GMM**					
GMM lag structure	**(t-2, t-3, t-4)**					
Sample	All firms		Irish Firms		Foreign firms	
	Non Exporters	Exporters	Non Exporters	Exporters	Non Exporters	Exporters
$\ln(VA/employee)_{t-1}$	0.647***	0.636***	0.773***	0.592***	0.630***	0.665***
	(0.034)	(0.034)	(0.081)	(0.082)	(0.048)	(0.035)
Ln(R&D/employee)	0.246**	0.207'	0.651	0.794***	0.137	0.211*
	(0.112)	(0.126)	(0.640)	(0.189)	(0.121)	(0.124)
Ln(Software/employee)	-1.104'	0.896***	0.148	-0.221	-0.356	1.063***
	(0.735)	(0.347)	(1.238)	(0.991)	(0.408)	(0.304)
Ln(Org. Cap./employee)	0.308***	0.154***	0.371**	-0.024	0.332***	0.198***
	(0.103)	(0.059)	(0.166)	(0.191)	(0.126)	(0.051)
Ln(IP Assets/employee)	0.113	0.078	0.086	0.526**	0.134	0.089
	(0.177)	(0.091)	(0.132)	(0.218)	(0.188)	(0.076)
Ln(Other Int./Empl)	0.208	-0.096	0.862	0.204	0.016	-0.182
	(0.212)	(0.140)	(0.660)	(0.265)	(0.187)	(0.190)
Time dummies	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
N observations	16405	9269	14536	6193	1869	3076
GMM instruments	140	140	139	139	139	139
P value AR2 test	0.613	0.416	0.324	0.942	0.324	0.247
P value Hansen test	1.000	1.000	1.000	1.000	1.000	1.000

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01. Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

R&D versus non-R&D investment

Having analysed the association between firm productivity and the aggregate investments in intangible assets first, and having looked at the specific types of intangibles next, we now provide an additional examination of the productivity-investment in KBC nexus. In fact it is of interest to contrast the effect of scientific R&D to that of the rest of intangible investments, which can be grouped into a broad group of non-R&D intangible investments. The results of this analysis are shown in Table 9, where we introduce a variable for non-R&D, computed by summing together the investments in software, organisational capital, IP assets and other intangible assets.

Investment in R&D is found to be a more important determinant of firm productivity, relative to investment in non-R&D intangible assets: both types of intangibles are positively and significantly associated with productivity, but, when all firms are analysed together, the estimated coefficient for investment in R&D is almost three times as large as the one for investment in non-R&D intangible assets.

This aggregate result hides some important heterogeneity. In line with the finding reported in Table 9 in the previous section we see that, for Irish firms' productivity, investment in R&D is a great deal more relevant than investment in non-R&D, both economically and statistically. Also for foreign-owned firms, the estimated effect of investment in R&D on productivity appears to be larger than the effect of investment in non-R&D. However, for this group of firms the gap between the effects of the two types of intangible investment is smaller, the link between investment in non-R&D intangible assets being statistically more significant than in the case of investment in R&D.

For manufacturing firms we find a very similar (and significant) effect of investment in R&D and in non-R&D intangible assets, while for service firms the estimated coefficient for investment in R&D is about 10 times larger than the one for investment in non-R&D intangible assets. In this latter case though, the significance of both effects are very strong.

For the remaining subgroup of firms analysed, firms in non-knowledge intensive industries and firms in non-food industries appear to have similar behaviours with respect to the impacts of investment in R&D and in non-R&D intangibles. In contrast, for firms in knowledge-intensive industries only investment in non-R&D intangible assets appears to be significantly linked to productivity. For firms in the food industries, even though both estimated coefficients are positive, these are not statistically significant.

The last table presented in this paper breaks out the effect of investments in R&D and in non-R&D intangibles on productivity across the three size groups. Estimates in Table A7, in the Appendix,

confirm the results discussed so far: investment in KBC affects the productivity of small and medium-sized firms (column 1-4), with this effect being limited to small Irish-owned firms when foreign firms are excluded from the analysed sample (columns 5-8). The impact of investment in R&D is found to be more sizable than investment in non-R&D intangibles, especially in the case of small Irish-owned firms.

Table 9: Investment in intangibles and firm productivity – R&D versus non-R&D spending

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent Variable					**Ln (VA/Empl)**				
Estimator					**1 step System GMM**				
GMM lag structure					**(t-2, t-3, t-4)**				
Sample	All firms	**Irish**	**Foreign**	**Service**	**Manuf.**	**KII =0**	**KII =1**	**Non-food**	**Food**
Ln (VA/Employee)$_{t-1}$	0.596***	0.690***	0.583***	0.630***	0.529***	0.574***	0.676***	0.475***	0.670***
	(0.034)	(0.060)	(0.041)	(0.036)	(0.103)	(0.042)	(0.055)	(0.101)	(0.100)
Ln (R&D/Employee)	0.493**	0.918***	0.398*	0.507*	0.326***	0.383***	0.317	0.336***	1.106
	(0.233)	(0.209)	(0.227)	(0.267)	(0.107)	(0.138)	(0.265)	(0.092)	(0.913)
Ln (Non-R&D/Employee)	0.172***	0.255*	0.208***	0.063*	0.338***	0.236***	0.127***	0.391***	0.609*
	(0.054)	(0.148)	(0.048)	(0.033)	(0.102)	(0.041)	(0.042)	(0.111)	(0.317)
Ln (Tangibles/Employee)	0.032	-0.224**	0.107	-0.070	0.044	0.037	-0.102	0.012	0.167***
	(0.103)	(0.092)	(0.135)	(0.114)	(0.159)	(0.090)	(0.151)	(0.165)	(0.057)
Ln (Wage/Employee)	0.332	-0.288	0.852**	0.955**	0.473**	0.300	0.630**	0.685***	0.224***
	(0.308)	(0.425)	(0.333)	(0.437)	(0.234)	(0.345)	(0.307)	(0.249)	(0.082)
Ln (Age)	0.016**	0.024***	0.023	0.008	0.010	0.013'	0.028***	0.002	0.020***
	(0.007)	(0.008)	(0.020)	(0.007)	(0.009)	(0.008)	(0.011)	(0.008)	(0.007)
Foreign-owned	0.072***			0.010	0.099***	0.074***	0.047**	0.098***	-0.034
	(0.018)			(0.019)	(0.019)	(0.023)	(0.020)	(0.015)	(0.047)
Constant	-0.009	-0.012'	0.055'	-0.033*	-0.017**	-0.010	-0.063*	-0.029**	-0.010
	(0.010)	(0.008)	(0.034)	(0.018)	(0.009)	(0.007)	(0.036)	(0.013)	(0.013)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
N observations	25674	20729	4945	17336	7809	21474	4200	6086	1723
GMM instruments	89	88	88	89	89	89	89	89	89
P value AR2 test	0.751	0.514	0.861	0.887	0.535	0.851	0.130	0.959	0.373
P value Hansen test	0.904	0.965	0.990	1.000	1	1.000	1	1	1

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

5 Conclusions and Policy Implications

The results of this analysis indicate that investment in KBC is strongly associated with firm productivity. On average, over and above other factors, a 10 per cent increase in the investment in KBC per employee is associated with a 2 per cent productivity gain. This result is driven to a large extent by the performance of foreign-owned firms, for which the link between investment in KBC and productivity is statistically stronger in comparison to Irish-owned firms. On the other hand, Irish-owned firms appear to benefit more than foreign-owned firms from investment in KBC.

One key finding of this research is that investment in KBC appears to be more important for productivity than investment in tangible assets which, over and above other factors, does not have a significant effect.

Investment in KBC impacts mostly on the productivity of SMEs (firms with 20 to 250 employees in this analysis). However, in the group of Irish-owned firms, it appears that investment in KBC has a positive and significant effect over and above other factors only for smaller firms (those with 20 to 50 employees). Taken together, these results suggest that investment in KBC impacts mostly at a lower point of the firm size distribution in the case of Irish-owned firms, and at a higher point when foreign-owned firms are also taken into account. The productivity of large firms, those with 250 and more employees appears to be mostly affected by investment in computer software, in organisational capital and in other intangible assets.

The effect of investment in KBC on productivity appears to be stronger in manufacturing firms than in services firms. Within manufacturing, firms in food industries appear to be more responsive to investments in KBC than firms in non-food industries. However, the estimates for firms in the food industries are not very robust across the different model specifications. This result could be explained by the smaller number of firms in this industry group relative to the other analysed industry groups.

Investment in R&D is consistently positively linked to firms' productivity across all firms, as well all as all sub-samples analysed, with the exception of large firms. The strongest link between R&D investment and productivity id found for smaller Irish-owned firms (firms with 20 to 50 employees in this analysis). Productivity in manufacturing firms appears to be more responsive to investment in R&D than the productivity of firms in services.

In the case of investment in non-R&D assets (software, organisational capital, IP assets and other intangibles), investment in software is most strongly associated with productivity gains (both economically and statistically). Higher investment in organisational capital also appear to affect positively the productivity of the various types of firms analysed, regardless of firms' ownership or sector of activity. In contrast, investing in IP assets affects mostly the productivity of foreign-owned

firms. Among Irish-owned firms, only the productivity of large firms is responsive to investment in IP assets. Investment in other intangibles (not elsewhere classified) impacts only on the productivity of large firms.

Finally, pooling together investments in the various non-R&D intangibles and contrasting their effect on productivity with that of investment in R&D, we find the responsiveness of productivity is larger to investment in R&D relative to investment in non-R&D intangible assets. This result is especially strong for the subgroup of Irish-owned firms, and within this group for smaller firms, those with 20 to 50 employees.

Taken together, our research results indicate that investments in various types of KBC assets have different effects on productivity across Irish-owned and foreign-owned firms. For Irish-owned firms, the largest productivity gains are found for investment in R&D intangible assets and in organisational capital. For foreign-owned firms, the largest productivity gains are linked to investment in non-R&D intangible assets such as computer software, intellectual property assets and organisational capital.

The empirical evidence provided in this paper suggests a number of implications for the design of policies and strategies aimed at improving productivity and competitiveness in the enterprise sector.

First, the results of this analysis indicate that a more comprehensive policy approach to incentivise investment in a broader range of intangible assets beyond R&D such as computer software, IP assets, and organisational capital could be beneficial.

Second, the evidence provided in this paper suggests that policy measures should be targeted to specific groups of firms, namely Irish-owned and foreign-owned. In the indigenous sector the issue to be addressed would be incentivising investment in non-R&D intangibles while in the case of foreign-owned firms further efforts to stimulate additional R&D investments in Ireland could be beneficial.

Third, the results of this analysis also suggest that a sectoral policy approach would be useful, particularly aiming to incentivise investment in intangibles in the services sector.

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Appendix

Table A1 Description of Variables

Variable	Description	Data Source
Intangibles per Employee	The value of investment and expenditures in intangible capital (sum of capitalised R&D expenditures; expenditure on purchased R&D services; capitalised expenditures on computer software; management fees; capitalised expenditure on patents, copyrights and licenses; expenditure on royalties and technical know-how; capitalised expenditure on other intangibles), divided by the number of employees.	CIP and ASI data, 2006-2012.
R&D per Employee	The sum of capitalised expenditure on R&D and expenditure on purchased R&D services, divided by the number of employees.	CIP and ASI data, 2006-2012.
Non-R&D per Employee	The sum of investment in non-R&D intangibles (capitalised expenditure on computer software; expenditure on management fees; capitalised expenditure on patents, copyrights and licenses; expenditure on royalties and know-how; capitalised expenditures on other intangibles) divided by the number of employees.	CIP and ASI data, 2006-2012.
Software per Employee	Capitalised expenditure on computer software, divided by the number of employees.	CIP and ASI data, 2006-2012.
Organizational Capital per Employee	Expenditures on management fees, divided by the number of employees.	CIP and ASI data, 2006-2012.
Intellectual Property (IP) Assets per Employee	The sum of capitalised expenditures on patents, copyrights and licenses and expenditure on royalties and technical know-how.	CIP and ASI data, 2006-2012.
Other Intangibles per Employee	Capitalised expenditure on other intangibles, divided by the number of employees.	CIP and ASI data, 2006-2012.
Tangibles per Employee	Investment in tangible capital assets, divided by the number of employees.	CIP and ASI data, 2006-2012.
Wage per Employee	Expenditures on wages reported by a firm, divided by the number of employees	CIP and ASI data, 2006-2012.
Age	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.
Value Added per Employee	The value of sales, net of the cost of materials and services, divided by the number of employees.	CIP and ASI data, 2006-2012.
Foreign	A binary variable taking equal to 1 if the firm is foreign-owned and 0 otherwise.	CIP and ASI data, 2006-2012.
Exporter	A binary variable equal to 1 if the firm reported export sales, and 0 otherwise.	CIP and ASI data, 2006-2012.
Food	A binary variable equal to 1 if the firm operates in the NACE Rev. 2 sectors 10, 11 or 12, and 0 otherwise.	CIP and ASI data, 2006-2012.
Non-Food	A binary variable equal to 1 if the firm operates in manufacturing industries, others than food industries, and 0 otherwise.	CIP and ASI data, 2006-2012.
KII (Knowledge Intensive Industries)	A binary variable equal t 1 if the firm operates in a knowledge-intensive industry, i.e. the NACE Rev. 2 sectors: 9, 19, 21, 26, 51, 58, 59, 60, 61, 62, 63, 64,	CIP and ASI data, 2006-2012, and Eurostat

	65, 66, 69, 70, 71, 72, 73, 74, 75, 78, 79, 80, and 0 otherwise.	indicators on High-Tech industry and Knowledge-Intensive services.
Manufacturing	A binary variable equal to 1 if the firm operates in a manufacturing industry, i.e. the NACE Rev. 2 sectors from 10 to 33 (included), and 0 otherwise.	CIP and ASI data, 2006-2012.
Services	A binary variable equal to 1 if the firm operates in a service industry, i.e. the NACE Rev. 2 sectors from 45 to 96 (included), and 0 otherwise.	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.

Table A2: The shares of firms investing in R&D and non-R&D, by ownership and export participation

	2006	2007	2008	2009	2010	2011	2012	2006	2007	2008	2009	2010	2011	2012
	Non-exporters							Exporters						
Irish-owned														
Firms with investment in R&D	4.7%	4.6%	6.8%	5.1%	6.1%	5.8%	12.8%	26.2%	26.6%	24.6%	25.7%	25.0%	23.4%	25.9%
Firms with investment in non-R&D	30.1%	32.7%	35.0%	36.3%	35.1%	36.7%	29.2%	37.0%	35.8%	38.7%	38.7%	39.1%	36.8%	33.7%
Firms with investment in KBC	**34.7%**	**37.3%**	**41.8%**	**41.5%**	**41.2%**	**42.5%**	**42.0%**	**63.1%**	**62.3%**	**63.2%**	**64.4%**	**64.1%**	**60.2%**	**59.6%**
Firms with no investment in KBC	65.3%	62.7%	58.2%	58.5%	58.8%	57.5%	58.0%	36.9%	37.7%	36.8%	35.6%	35.9%	39.8%	40.4%
	Foreign-owned													
Firms with investment in R&D	8.0%	8.8%	9.6%	12.2%	9.9%	9.7%	11.6%	21.8%	23.7%	22.1%	23.2%	22.6%	23.2%	21.8%
Firms with investment in non-R&D	53.6%	55.1%	55.9%	54.4%	54.8%	54.2%	51.9%	50.9%	51.1%	52.2%	51.2%	50.7%	51.7%	53.8%
Firms with investment in KBC	**61.5%**	**63.8%**	**65.5%**	**66.6%**	**64.8%**	**63.9%**	**63.5%**	**72.6%**	**74.9%**	**74.3%**	**74.4%**	**73.3%**	**74.9%**	**75.6%**
Firms with no investment in KBC	38.5%	36.2%	34.5%	33.4%	35.2%	36.1%	36.5%	27.4%	25.1%	25.7%	25.6%	26.7%	25.1%	24.4%

Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

Notes: Firms with investment in R&D: Firms with capitalised R&D and firms with purchased R&D. *Firms with investment in non-R&D*: Firms with capitalised expenditures on software, copyrights, patents, licences, other intangible assets; firms with expenditure on organisational capital (management fees), royalties and technical know-how. *Firms with investment in KBC*: Firms with investment in R&D and firms with investment in non R&D assets.

Table A3: The share of firms investing in R&D and non-R&D, by ownership and size class

	2006	2007	2008	2009	2010	2011	2012	2006	2007	2008	2009	2010	2011	2012
	Small							Medium						
Irish-owned														
Firms with investment in R&D	9.3%	9.8%	10.5%	9.1%	11.9%	10.7%	18.4%	11.5%	9.8%	11.5%	13.0%	10.5%	11.8%	13.8%
Firms with investment in non-R&D	29.3%	30.7%	33.6%	34.2%	32.3%	34.5%	26.4%	35.2%	37.1%	38.2%	40.3%	40.5%	38.1%	34.2%
Firms with investment in KBC	**38.6%**	**40.5%**	**44.1%**	**43.3%**	**44.1%**	**45.2%**	**44.8%**	**46.7%**	**46.8%**	**49.7%**	**53.2%**	**51.1%**	**49.9%**	**48.1%**
Firms with no investment in KBC	61.4%	59.5%	55.9%	56.7%	55.9%	54.8%	55.2%	53.3%	53.2%	50.3%	46.8%	48.9%	50.1%	51.9%
Foreign-owned														
Firms with investment in R&D	14.4%	14.1%	13.2%	15.0%	12.9%	14.5%	19.1%	16.7%	18.0%	19.3%	19.9%	19.1%	17.9%	15.5%
Firms with investment in non-R&D	47.8%	50.2%	52.4%	51.0%	51.5%	49.8%	48.6%	53.1%	53.5%	53.7%	52.3%	51.8%	54.7%	57.2%
Firms with investment in KBC	**62.2%**	**64.3%**	**65.6%**	**66.0%**	**64.3%**	**64.4%**	**67.6%**	**69.7%**	**71.5%**	**72.9%**	**72.3%**	**70.8%**	**72.6%**	**72.7%**
Firms with no investment in KBC	37.8%	35.7%	34.4%	34.0%	35.7%	35.6%	32.4%	30.3%	28.5%	27.1%	27.7%	29.2%	27.4%	27.3%

	2006	2007	2008	2009	2010	2011	2012
	Large						
Irish-owned							
Firms with investment in R&D	17.6%	18.3%	18.3%	16.0%	12.6%	11.6%	13.3%
Firms with investment in non-R&D	50.3%	51.8%	58.1%	57.7%	57.9%	56.9%	60.2%
Firms with investment in KBC	**67.9%**	**70.1%**	**76.3%**	**73.7%**	**70.5%**	**68.5%**	**73.5%**
Firms with no investment in KBC	32.1%	29.9%	23.7%	26.3%	29.5%	31.5%	26.5%
Foreign-owned							
Firms with investment in R&D	20.4%	20.6%	17.9%	22.4%	21.8%	22.3%	19.5%
Firms with investment in non-R&D	55.2%	55.6%	56.2%	55.7%	55.3%	53.3%	51.5%
Firms with investment in KBC	**75.6%**	**76.2%**	**74.1%**	**78.1%**	**77.2%**	**75.6%**	**71.0%**
Firms with no investment in KBC	24.4%	23.8%	25.9%	21.9%	22.8%	24.4%	29.0%

Source: Authors' calculations based on CIP and ASI data. Firms with 20 or more employees are included in the analysis.

Notes: Firms with investment in R&D: Firms with capitalised R&D and firms with purchased R&D. *Firms with investment in non-R&D*: Firms with capitalised expenditures on software, copyrights, patents, licences, other intangible assets; firms with expenditure on organisational capital (management fees), royalties and technical know-how. *Firms with investment in KBC*: Firms with investment in R&D and firms with investment in non R&D assets.

Table A4: Intensity of investment in all intangible assets, CIP, 2006-2012

	Non-exporter	Exporter	Total	
Irish	5.86	9.94	8.58	Mean
	0.97	2.22	1.67	Median
	1,823	3,631	5,454	Firm-Year Observations
Foreign	80.51	154.91	146.81	Mean
	5.67	6	5.98	Median
	232	1,898	2,130	Firm-Year Observations
Total	14.29	59.71	47.4	Mean
	1.11	3.03	2.33	Median
	2,055	5,529	7,584	Firm-Year Observations

Notes: The summary statistics are obtained using only observations with positive investment values. The mean and median figures are in thousands Euros, per employee, in constant 2010 prices.

Source: Authors' calculations based on the CIP data. Firms with 20 or more employees are included in the analysis.

Table A5: Intensity of investment in all intangible assets, ASI, 2006-2012

	Non-exporter	Exporter	Total	
Irish	4.39	9.89	5.39	Mean
	1	1.79	1.1	Median
	7,465	1,665	9,130	Firm-Year Observations
Foreign	76.2	129.21	98.16	Mean
	3.37	4.86	3.84	Median
	1,567	1,108	2,675	Firm-Year Observations
Total	16.85	57.57	26.41	Mean
	1.2	2.81	1.45	Median
	9,032	2,773	11,805	Firm-Year Observations

Notes: The summary statistics are obtained using only observations with positive investment values. The mean and median figures are in thousands Euros, per employee, in constant 2010 prices.

Source: Authors' calculations based on ASI data. Firms with 20 or more employees are included in the analysis.

Table A6: Investment in intangibles and firm productivity – specific intangibles, one by one

	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)
Dep. Var.					**Ln (VA/Employee)**				
Estimator					**1 step System GMM**				
GMM lag structure					**(t-2, t-3, t-4)**				
$\ln(VA/Employee)_{t-1}$	0.622***	0.609***	0.686***	0.628***	0.644***	0.602***	0.653***	0.631***	0.635***
	(0.064)	(0.048)	(0.053)	(0.037)	(0.043)	(0.060)	(0.049)	(0.032)	(0.028)
Ln(R&D/Employee)	0.597**					0.635***	0.577***	0.367**	0.296*
	(0.288)					(0.238)	(0.201)	(0.180)	(0.174)
Ln(Software/Employee)		0.968**				1.310***	1.340***	1.423***	1.304***
		(0.388)				(0.467)	(0.447)	(0.471)	(0.464)
Ln (Organiz. Cap. /Employee)			0.167***				0.174***	0.222***	0.201***
			(0.064)				(0.057)	(0.061)	(0.055)
Ln(IP Assets/Employee)				0.156***				0.087**	0.069'
				(0.056)				(0.038)	(0.044)
Ln(Other Intangibles/Employee)					0.113				0.100
					(0.141)				(0.160)
ln(Tangibles/Employee)	0.013	-0.001	0.000	-0.061	0.088	0.033	0.029	-0.009	0.032
	(0.123)	(0.122)	(0.095)	(0.098)	(0.070)	(0.136)	(0.124)	(0.109)	(0.073)
ln(Wage/Employee)	0.089	0.575	0.060	0.475	0.633*	0.215	0.012	0.175	0.442
	(0.418)	(0.420)	(0.478)	(0.385)	(0.384)	(0.397)	(0.410)	(0.394)	(0.374)
ln(Age)	0.018**	0.011*	0.018***	0.013*	0.010*	0.016**	0.018***	0.017***	0.013**
	(0.008)	(0.006)	(0.007)	(0.007)	(0.006)	(0.008)	(0.007)	(0.006)	(0.005)
Foreign-owned	0.100***	0.083***	0.085***	0.075***	0.069***	0.094***	0.084***	0.074***	0.060***
	(0.020)	(0.019)	(0.018)	(0.020)	(0.017)	(0.019)	(0.017)	(0.019)	(0.020)
Constant	-0.008	-0.022**	-0.003	-0.020**	-0.025**	-0.005	-0.009	-0.005	-0.021*
	(0.009)	(0.011)	(0.013)	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
N observations	25674	25720	25720	25720	25720	25674	25674	25674	25674
GMM instruments	72	72	72	72	72	89	106	123	140
P value AR2 test	0.556	0.851	0.685	0.983	0.831	0.562	0.550	0.671	0.665
P value Hansen test	0.369	0.702	0.537	0.515	0.451	0.954	0.999	1.000	1.000

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
Source: Authors' estimates based on CIP and ASI data.

Table A7: Investment in intangibles and firm productivity – R&D vs. Non-R&D spending, by size groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.	**Ln (VA/Employee)**							
Estimator	**1 step System GMM**							
GMM lag structure	**(t-2, t-3, t-4)**							
Sample					**Irish firms only**			
	SMEs	**Small**	**Medium**	**Large**	**SMEs**	**Small**	**Medium**	**Large**
Ln (VA/Employee)$_{t-1}$	0.535***	0.510***	0.660***	0.716***	0.593***	0.518***	0.700***	0.809***
	(0.040)	(0.030)	(0.059)	(0.059)	(0.062)	(0.096)	(0.067)	(0.129)
Ln (R&D/Employee)	0.494***	0.372**	0.348**	0.315	**0.693***	**1.555****	**0.142**	**-0.281**
	(0.190)	(0.177)	(0.165)	(0.231)	**(0.397)**	**(0.784)**	**(0.396)**	**(0.488)**
Ln (Non-R&D/Employee)	0.233***	0.170**	0.201**	0.081	**0.413****	**0.469****	**0.159**	**0.163**
	(0.080)	(0.070)	(0.088)	(0.090)	**(0.173)**	**(0.187)**	**(0.112)**	**(0.283)**
Ln (Tangibles/Employee)	0.145	0.018	-0.066	-0.035	-0.218**	-0.302***	-0.087	-0.030
	(0.115)	(0.078)	(0.068)	(0.191)	(0.102)	(0.107)	(0.086)	(0.085)
Ln (Wage/Employee)	0.659*	1.241***	0.491	0.667	0.325	0.443	0.816**	0.123
	(0.373)	(0.390)	(0.441)	(0.553)	(0.463)	(0.456)	(0.378)	(0.915)
Ln (Age)	0.015**	0.009	0.012	-0.005	0.014**	0.017**	-0.005	0.066
	(0.006)	(0.007)	(0.010)	(0.022)	(0.007)	(0.008)	(0.008)	(0.048)
Foreign-owned	0.061**	0.073***	0.027	0.053**				
	(0.025)	(0.021)	(0.032)	(0.027)				
Constant	-0.018'	-0.030**	-0.030**	-0.041	-0.012	-0.021**	-0.030**	-0.078***
	(0.012)	(0.014)	(0.015)	(0.041)	(0.010)	(0.010)	(0.013)	(0.024)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
N observations	23629	14560	9069	2045	19756	12966	6790	973
GMM instruments	89	89	89	89	88	88	88	88
P value AR2 test	0.731	0.439	0.682	0.512	0.678	0.756	0.999	0.379
P value Hansen test	0.881	0.955	0.995	0.999	0.948	0.960	0.982	1.000

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.

Source: Authors' estimates based on CIP and ASI data.

Table A8: Investment in intangibles and firm productivity – aggregate intangibles – 2 productivity lags

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Dep. Var.	Ln (VA/Empl)	Ln (VA/Empl)	Ln (VA/Employee)								
Estimator	**Pooled OLS**	**Fixed Effects**	**1 step System GMM**								
GMM lag structure			**(t-2, t-3, t-4)**								
Sample	All firms	All firms	All firms	**Irish**	**Foreign**	**Services**	**Manufacturing**	**KII=0**	**KII=1**	**Non-Food Manuf.**	**Food**
Ln (VA/Employee)$_{t-1}$	0.727***	0.121***	0.513***	0.698***	0.435***	0.528***	0.588***	0.553***	0.452***	0.512***	0.647***
	(0.044)	(0.029)	(0.073)	(0.080)	(0.103)	(0.076)	(0.051)	(0.051)	(0.120)	(0.050)	(0.042)
Ln (VA/Employee)$_{t-2}$	0.119***	-0.072***	0.086	0.036	0.140*	0.094'	0.088***	0.075	0.222***	0.121***	0.159***
	(0.025)	(0.025)	(0.061)	(0.049)	(0.078)	(0.058)	(0.031)	(0.058)	(0.074)	(0.031)	(0.005)
Ln (Intangibles/Empl.)	**0.104****	**0.190****	**0.183*****	**0.310***	**0.242*****	**0.140*****	**0.225*****	**0.331*****	**0.161****	**0.298*****	**0.386*****
	(0.042)	**(0.091)**	**(0.051)**	**(0.186)**	**(0.041)**	**(0.032)**	**(0.064)**	**(0.051)**	**(0.076)**	**(0.071)**	**(0.052)**
Ln (Tangibles/Empl.)	0.042*	0.022	-0.097	-0.285**	0.107	-0.048	-0.111	-0.084	-0.282*	-0.089	0.038***
	(0.023)	(0.034)	(0.096)	(0.144)	(0.119)	(0.093)	(0.119)	(0.078)	(0.158)	(0.162)	(0.011)
Ln (Wage/Empl.)	0.430***	1.178***	0.380	-0.448	0.690'	0.738**	0.344	0.795***	1.100**	1.257***	0.048
	(0.063)	(0.067)	(0.441)	(0.409)	(0.434)	(0.372)	(0.241)	(0.230)	(0.512)	(0.293)	(0.307)
Ln (Age)	0.006	0.032	0.013	0.026***	0.022	0.011	0.005	0.007	0.007	-0.000	0.011***
	(0.008)	(0.040)	(0.013)	(0.009)	(0.030)	(0.014)	(0.008)	(0.011)	(0.015)	(0.009)	(0.004)
Foreign-owned	0.009	0.042*	0.073***			0.018	0.083***	0.089**	0.021	0.087***	-0.053
	(0.011)	(0.024)	(0.025)			(0.028)	(0.015)	(0.036)	(0.027)	(0.008)	(0.070)
Constant	-0.045**	0.032**	-0.013	-0.009	-0.021	-0.027	-0.014	-0.019'	-0.091*	-0.039***	-0.012**
	(0.018)	(0.016)	(0.022)	(0.010)	(0.052)	(0.023)	(0.012)	(0.013)	(0.052)	(0.011)	(0.006)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N observations	17394	17394	17394	13759	3635	11022	5993	14646	2748	4639	1354
GMM instruments			74	73	73	74	74	74	74	74	74
P value AR2 test			0.918	0.635	0.830	0.928	0.799	0.864	0.842	0.109	0.911
P value Hansen test			0.556	0.597	0.767	1.000	1.000	0.981	1.000	1	1

Notes: Standard errors clustered at the NACE 2-digit sector level in parentheses; ' p <0.15, * p <0.10, ** p <0.05, ***p < 0.01.
Value Added (VA) was calculated as the difference between turnover and the cost of material and services.
*Source: A*uthors' estimates based on CIP and ASI data.

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