Gabinete de Estratégia e Estudos

GEE Paper

145

Março de 2020

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Rua da Prata, n.º 8 – 1149-057 Lisboa – Portugal
www.gee.gov.pt
ISSN (online): 1647-6212

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Intangible investments and productivity performance[1]

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Abstract

Companies in advanced economies are facing new challenges. Investment in intangible assets – such as R&D expenditures, ICT activities, the cost of training employees and spending on improving the organizational process – has gained relevance to overcome market pressure. In the last decade, many studies discussed the impact of intangible investment on firms' performance. However, comparison of the effect of different types of intangible investments is less well explored. The paper aims to fill this gap by assessing the impact of several intangible investments on productivity using for the first-time data from the EIB Survey on Investment (EIBIS) covering all 28 EU members, in the period 2015-2017. We allow intangible investments to affect productivity through innovation, using an augmented version of the Crépon-Duguet-Mairesse (1998) model. Our results show that all types of intangible investments positively impact labour productivity. However, ICT and acquisition of new skills are more important for explaining productivity gains than R&D investment and organizational improvements. Furthermore, R&D and ICT investments also affect productivity indirectly through their effects on innovation, which itself increases productivity.

JEL Classification: O30, O44, O52

Keywords: R&D; ICT; Intangible investments; Innovation; Productivity

Note: This article is sole responsibility of the authors and do not necessarily reflect the positions of GEE or the Portuguese Ministry of Economy. This paper was one of the winners of the Call for Papers about R&D and Innovation in Digital Economy (GEE and ANI)

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[1] The views expressed in this paper are those of the authors and do not necessarily reflect the views of the European Investment Bank or the European Commission. The present version of the paper refers to the work carried until 29/11/2019.

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1. Introduction

Investment in intangible assets has increased over the last decades, driven by changes in industrial market structure (**Haskel and Westlake, 2017**). The manufacturing sector has become oriented towards service and customers, and the service sector is increasingly being mechanized, through artificial intelligence and robotisation (**Rebordão, 2005**). The development and easy diffusion of new technologies across all industries, thanks to digitalisation, are changing sectoral patterns. Information and communication technologies (ICT) are affecting companies' organizational structure and commercial strategy, by providing them with new ways of selling products and services (e.g. e-commerce) or by giving easy, fast access to data (e.g. information about customers). Technological change is also affecting the structure of the labour market. New job positions in the ICT sector are being created and updating knowledge of workers gets more important.

Due to these evolutions, companies are facing new challenges. In order to maintain their position in the market, they continuously have to perform better because competition is becoming more global due to the computer network. Investment in intangible assets (such as R&D activities, intellectual property rights - patents, trademarks and design -, software, data, IT network, and training) has gained relevance in overcoming market pressure. Research and Development (R&D) activities help companies to develop new products, services or processes, or to improve existing ones (**Crépon et al. 1998**; **Hall et al. 2013**). Providing continuous training enhances workers' performance (**Chi and Bjork, 1991**; **Llorens et al. 2002**) and investment in ICT affects companies' competitiveness and supports their internationalisation (**Consoli, 2012**).

Many authors have studied the effect of intangible assets or investments on firms' performance in the last decades.[7] The majority of studies find a positive impact of intangible investment on firms' performance, measured by sales growth (**Cucculelli and Bettinelli, 2015**), total factor productivity (**Dal Borgo et al. 2013**), labour productivity (**Roth and Thum, 2013**) or innovativeness (**Montresor and Vezzani, 2016**; **Ciriaci, 2011**). However, comparison of the effect of different types of intangible investments as well as understanding the obstacles to investment faced by firms are less well documented in the literature.

This paper aims to fill these gaps using data of the EIB Investment Survey (EIBIS). These effects are assessed directly and indirectly through innovation behaviour, using an augmented version of the Crépon-Duguet-Mairesse (1998) model. Intangible investments comprise R&D expenditure, ICT activities, the cost of training employees and spending on improving the organizational process. Furthermore, since countries and sectors encounter different macro-economic conditions, as a complementary analysis, we also assess differences between sectors (manufacturing *versus* services) and EU regions (e.g., West and North Europe, South Europe and Central and East Europe). Indeed, previous studies have revealed that the effect of intangible investments on productivity can differ across sectors (**Bobilo et al. 2006**), between countries (**Marrocu et al. 2009**) or ages of firms (**Cincera and Veugelers, 2014**).

We argue this paper contributes to the literature in several ways. First, to the best of our knowledge, this is the first study assessing the impact of more than two intangible investments on innovation and

[7] For a survey of the literature see e.g. **Draca et al.** (2007), **Sveikauskas** (2007),**Consoli** (2012), **Biagi** (2013), **Cardona et al.**(2013), **Ugur et al.** (2016) and **Stanley et al.** (2018).

productivity.[8] Second, we use a database composed of firms in all 28 EU member states, whereas other studies usually used micro-data of only one country.[9] In this way, we are able to compare the performance of different EU Member states. Lastly, we use a database (EIBIS) that has not previously been used for a similar exercise.

The remainder of this paper is organized as follows. Section 2 describes the theoretical framework of the study and summarizes the main findings in the literature about the effects of intangible investments on productivity and the obstacles to innovation activities. The description of the data and the methodological framework are discussed in Section 3 and 4. Section 5 reports the results of the study. The last section is a conclusion.

[8] For example, **Hall et al.** (2013) and **Alvarez** (2016) analyzed the effect of two different intangibles (R&D and ICT) on innovation and productivity. However, we include two additional intangible categories, namely the acquisition of new skills, through training of employees, and investment in organization and business process improvements.

[9] For example, **Crépon et al.** (1998) used data from French firms, **Castellacci** (2011) Norwegian firms, **Hall et al.** (2013) Italian firms, **Álvarez** (2016) Chilean firms and **Czarnitzki and Delanote** (2017) Belgian firms.

2. Theoretical background

A pioneering study about the effect of intangible investment on productivity is that of **Griliches** (1979). He introduced an augmented form of the **Cobb and Douglas** (1928) production function including knowledge stock (K) as an input, in addition to physical capital stock (C) and labour stock (L), as expressed in equation (1). Q refers to the firm's production output, A represents the technology used for producing Q and e is a disturbance error term that includes unmeasured (or unobservable) factors. α, β, and γ are the model's parameters of interest.

$$Q_{it} = Ae^{\lambda t}C_{it}^{\alpha}L_{it}^{\beta}K_{it}^{\gamma}e^{u_{it}} \quad (1)$$

Based on this framework, several authors have analysed the impact of R&D activities (see e.g. **Hall and Mairesse, 1995**; **Smith et al., 2004**; **Ortega-Argilés et al. 2011**) and/or ICT investments (see e.g., **Greenan and Mairesse, 2000**; **Bugamelli and Pagano, 2004**; **Wilson, 2009**) on firm productivity. Generally, these studies show evidence of a positive effect of R&D expenditure or ICT investment on firm productivity. However, using the knowledge production function approach requires the use of panel or time-series data in order to estimate capital stocks. Nevertheless, with the use of survey data, information covering several periods is often not available, since the same firms are not surveyed each time. Due to the cross-sectional nature of surveys, solving endogeneity and causality issues are challenging (**Mairesse and Mohnen, 2010**).

To overcome these limitations, **Crépon et al.** (1998) proposed an empirical approach to assess the productivity impacts of research and innovation, through the so-called CDM model.[10] The CDM model was designed based on the three stages of the innovation process to correct for the endogeneity of R&D and innovation output as well as for the selectivity of R&D activities (**Mairesse and Mohnen, 2010**). The first stage of the model consists of the decision to invest or not in R&D activities and how much to spend on them. The second refers to innovation output, such as the share of the firm's innovative sales and the number of patents which are driven by innovation input (R&D). The last step contains a productivity function, which includes innovation output. The main difference between the CDM model and the **Griliches** (1979) production function approach lies in using R&D as an input in the innovation process rather than as an input in the production function. Doing so, R&D enhances productivity but only indirectly through innovation output.

In order to include other dimensions of intangible investments, the literature has used an augmented version of the CDM model. For example, in addition to R&D activities, data on ICT investments has also been included in the model (see e.g. **Polder et al. 2009**; **Hall et al. 2013**; **Álvarez, 2016**). According to **Hall et al.** (2013), who used data on Italian manufacturing firms, both R&D and ICT investments affect firms' productivity directly and indirectly (through innovation output). Similarly, based on a sample of Chilean firms, **Álvarez** (2016) provided evidence that ICT investment increases productivity not only indirectly through innovation but also directly. He argues that ICT investment, rather than R&D expenditure, is more relevant to increase productivity in services. This finding is also in line with **Hall et al.** (2013) who revealed that ICT investment could be a better predictor of productivity gains than the

[10] The CDM model is not restricted to cross-sectional data. It can also be used with panel data but is more often estimated on cross-sectional or repeated cross-sectional data.

innovation propensity. However, according to other studies (see e.g. **Brynjolfsson and Hitt, 2000**; **Bresnahan et al. 2002**; **Bugamelli and Pagano, 2004**), the effect of ICT investment on productivity depends on two preconditions: adopting new business practices or workplace reorganization and increasing the skills of the labour force.

Polder et al. (2009) highlighted the importance of organizational innovation to achieve higher levels of productivity, providing evidence that product and process innovation only have a significant effect on firm' performance when implemented together with organizational innovation. For instance, it is suggested that the efficient new software requires qualified employees (**Bugamelli and Pagano, 2004**). Specific human capital skills are also needed to develop and successfully implement R&D projects (**Blanes and Busom, 2004**). Furthermore, changes in data processing as the result of new software are also associated with the need to change workplace and business practices. Indeed, if the information is more easily and quickly available, employees also need to have more autonomy in the decision-making process in order to enhance productivity, as suggested by **Brynjolfsson and Hitt** (2000). Similarly, the implementation of a new production chain after the development a new product should be linked with changes in organizational structure to ensure higher productivity levels. An example of that is introducing a new work practice procedure that can lead to more efficient use of equipment/machinery and cost reduction, such as stopping production lines when they are not operating at maximum capacity or implementing a quality control system to reduce the level of waste and non-compliant products.

Another important dimension in the link between investment and productivity is related to obstacles to investment or business activity, which can influence entrepreneurship and the strategic decision to invest. The existing literature using investment or innovation survey data listed essentially 4 groups of factors hampering investment activities: i) access to finance and related cost; ii) availability of qualified human resources and supportive infrastructure; iii) market conditions (e.g. competition and demand for product or services); and iv) regulation. Table 1 reports all the factors included in firm-level surveys covering all EU countries.

D'Este et al. (2012) make a distinction between the so-called *revealed* and *deterring* barriers to innovation. The former refers to the perception of their existence once firms were faced with them because they were involved in innovation activities, whereas the latter corresponds to insurmountable obstacles to innovation and/or investment activities. This distinction could explain why some authors (see e.g. **Galia and Legros, 2004**; **Iammarino et al. 2009**; **Castellacci, 2011**; **D'Este et al. 2012**) found positive correlations between innovation activities and their obstacles.

Table 1. Barriers and obstacles to innovation, investment and business activity by survey

Community Innovation Survey (CIS)	**Survey on the access to finance of enterprises (SAFE)**	**EIB Investment Survey (EIBIS)**
Barriers to innovation activity (1)	Obstacles to business activity (2)	Obstacles to investment activities (3)
- **Lack of internal finance for innovation** - **Lack of credit or private equity** - **Lack of skilled employees within the enterprise** - **Difficulties in obtaining government grants or subsidies for innovation** - **Lack of collaboration partners** - **Uncertain market demand for ideas for innovations** - **Too much competition in the market**	- Finding customers - Competition - Access to finance - Costs of production or labour - Availability of skilled staff or experienced managers - Regulation	- Demand for products or services - Availability of staff with the right skills - Energy costs - Access to digital infrastructure - Labour market regulations - Business regulations and taxation - Availability of adequate transport infrastructure - Availability of finance - Uncertainty about the future

Source: Authors' own elaboration based on CIS, SAFE and EIBIS questionnaires.
Note:(1) Refers to question 12.3. in CIS: *How important to your enterprise were the following barriers to innovation? Where the degree of importance is the following: 0 not important at all, 1 low, 2 medium and 3 high;* (2) Refers to question 0b. in SAFE: *How important have the following problems been for your enterprise in the past six months? Please answer on a scale of 1-10, where 1 means it is not at all important and 10 means it is extremely important;* (3) Refers to question 38 in EIBIS: *Thinking about your investment activities (…), to what extent is each of the following an obstacle? Is it a major obstacle, a minor obstacle or not an obstacle at all?*

However, for other authors (see e.g. **Savignac, 2008**; **Mancusi and Vezzulli, 2010**) the presence of a positive relationship between obstacles and innovation behaviour could also be due to endogeneity issues. Indeed, since information from surveys shows the results of entrepreneurs' perception and self-evaluation concerning barriers or obstacles, this subjectivity could also be a potential source of bias. Furthermore, **Iammarino et al.** (2009) argue that innovative firms are also more likely than non-innovative ones to experience problems related with innovation activities. To correct such potential sources of bias, all firms that are not interested in innovating for reasons not related with barriers to innovation are often excluded from the analysis (**Savignac, 2008**; **Mancusi and Vezzulli, 2010**; **D'Este et al. 2012**). Using a sample of UK firms and CIS data and after controlling for selection bias, **D'Este et al.** (2012) find that cost and market barriers can prevent firms from innovating (negative effect), whereas knowledge and regulation barriers are more *revealed* obstacles (positive effect). This latter effect is due to the result of "learning from direct experience" from being involved in innovation activities.

Although obstacles to investment activities are not the core of our research paper, they are included as control variables in the model specification since they can influence the investment-productivity relationship indirectly. In addition, obstacles are a good *proxy* for macro-economic conditions and the challenges firms face. Identifying barriers discouraging investment activities is particularly important from a policy perspective, since it helps to detect market gaps and assist in designing better and more effective policy intervention.

3. Data and descriptive statistics

The data used in the study comes from the EIB Investment Survey (EIBIS), an annual survey that gathers qualitative and quantitative information on investment activities, financing requirements and difficulties firms are faced with in all 28 EU Member states. The first wave of interviews took place in 2016 and refers to firms' activity in the previous financial year. We use data from the three waves covering the period 2015-2017. The surveys involve interviews with some 12,500 firms per year. The survey answers were matched with the Bureau van Dijk ORBIS database, in order to obtain additional financial accounting data about the companies. After selecting all observations with non-missing values on our variables of interest, the final sample has 24,126 firm-year observations.

The sample is composed of SMEs (83%) and large firms located in EU28 and operating in manufacturing (30%), construction (22%), services (23%) and infrastructure (24%) sectors (Table 2). Firms more than 20 years old represent about 60% of the sample. About 48% are exporters, 28% are part of a group and 84% invested in intangibles. R&D investments[11] represent about 13% of the total investment[12], followed by ICT investments[13] (9%) and organizational/business process improvements (5%). The amount of investment in the training of employees/acquisition of new skills only corresponds to 3% of the total investment. However, the propensity to invest in training is the highest among all intangibles (69% for training *versus* 24% for R&D, 31% for organizational improvement and 63% for ICT).

Table 2. Descriptive Statistics

Total investment per employee (€)	26,149 €	N° of major obstacles	2.29
Intangible investment per employee (€)	7,622 €	Being faced with a major obstacle (Y/N)	74%
R&D investment per employee (€)	3,311 €	Turnover per employee (€)	389,885 €
ICT investment per employee (€)	2,264 €	Competition level	0.883
New skills investment per employee (€)	686 €	SMEs	83%
Organizational improvements investment per employee (€)	1,361 €	N° of employees	215
Investing in Intangibles (Y/N)	84%	Age: 0-5 years	4%
Investing in R&D (Y/N)	24%	Age: 5-9 years	11%
Investing in ICT (Y/N)	63%	Age: 10-19 years	26%
Investing in new skills (Y/N)	69%	Age: > 20 years	59%
Investing in organizational improvements (Y/N)	31%	Belonging to a group (Y/N)	28%
Major obstacle: Demand for products or services	22%	Exporter (Y/N)	48%
Major obstacle: Availability of staff with the right skills	44%	Above maximum capacity (Y/N)	5%
Major obstacle: Energy costs	22%	Sector: Manufacturing	30%
Major obstacle: Access to digital Infrastructure	9%	Sector: Construction	22%
Major obstacle: Labour market regulations	28%	Sector: Services	23%

[11] R&D also includes the acquisition of intellectual property.
[12] Tangible and intangible investments.
[13] ICT comprises software, data, IT networks and website activities.

Major obstacle: Business regulations and taxation	30%	Sector: Infrastructure	24%
Major obstacle: Availability of adequate transport infrastructure	14%	Region: Central and East Europe	42%
Major obstacle: Availability of finance	21%	Region: South Europe	18%
Major obstacle: Uncertainty about the future	37%	Region: West and North Europe	40%

Note: N° of observations = 24,126. Central and East Europe includes Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. South Europe includes Cyprus, Greece, Italy, Malta, Spain and Portugal. West and North Europe includes Austria, Belgium, Denmark, Ireland, Germany, Finland, France, Luxembourg, Netherlands, Sweden and UK.

About 74% of firms are faced with a major obstacle to investment activities. The availability of staff with the right skills (44%) and uncertainty about the future (37%) are the major obstacles most frequently cited. In turn, obstacles related to accessing digital infrastructure (9%) and access to transport infrastructure (14%) are the least mentioned as major obstacles.

Firms investing in intangible are faced with fewer major obstacles than their counterpart, and they also display a higher propensity to innovate and a higher amount of turnover per employee (Table 3).

Table 3. Mean major obstacles, innovation and productivity, by investment decision

Variables	Intangible Yes		Intangible No		Diff Yes-No	
	Mean	Std. Err.	Mean	Std. Err.		
N° of major obstacles	2.27	0.01	2.38	0.03	-0.11	***
Innovation (Yes/No)	0.40	0.00	0.08	0.00	0.32	***
Turnover per employee (€)	408,929	28,612	293,026	56,080	115,902	*

Note: N° of observations: Intangible Yes = 20,162; Intangible No = 3,964. Significance level: *** p<0.01, * p<0.1.

On average, firms in South Europe are faced with a higher number of major obstacles than those in other European regions (Table 4). Except for the availability of staff with the right skills, all the other obstacles hamper more firms in South Europe.

Table 4. Major obstacles to investment activities, by European regions

Variable	Central and East Europe	South Europe	West and North Europe
N° of obstacles	2.389	3.419	1.679
Demand for products or services	0.234	0.342	0.158
Availability of staff with the right skills	0.501	0.403	0.402
Energy costs	0.219	0.403	0.134
Access to digital infrastructure	0.058	0.164	0.083
Labour market regulations	0.289	0.418	0.219
Business regulations and taxation	0.318	0.485	0.200
Availability of adequate transport infrastructure	0.153	0.239	0.094
Availability of finance	0.220	0.358	0.144

Uncertainty about the future	0.398	0.606	0.245

Note: N° of observations: Central and East Europe= 10,013; South Europe = 4,386. West and North Europe = 9,727.

Firms located in South Europe also register a greater intensity of intangible investment and a higher propensity to innovate (Table 5). However, the average level of labour productivity is lower than for firms in West and North Europe, which register more modest investment intensity but higher performance. It is also interesting to see that firms located in regions investing the most are the ones that complain most about obstacles to investment activities, suggesting the prevalence of a perception about the obstacles because firms have experienced them, as highlighted by **D'Este et al.** (2012).

Table 5. Mean intangible investments, innovation and productivity, by European regions

Variable	Central and East Europe	South Europe	West and North Europe
Intangible investment per employee (€)	1,307	22,369	7,473
R&D investment per employee (€)	389	9,805	3,392
ICT investment per employee (€)	385	6,291	2,383
New skills investment per employee (€)	163	1,868	691
Organiz. improv. invest. per employee (€)	371	4,405	1,008
Innovation (Yes/No)	30.2%	39.4%	37.2%
Turnover per employee (€)	214,453	429,581	552,577

Source: Authors' own elaboration.
Note: N° of observations: Central and East Europe= 10,013; South Europe = 4,386. West and North Europe = 9,727.

Concerning differences between sectors, the results of the t-test for equality of means (Table 6) show that firms operating in the manufacturing sector are more likely to invest in all intangibles[14] (except in ICT) and to innovate.

[14] This finding is in line with **Coad and Vezzani** (2017), who found a positive correlation between the manufacturing sector and Business R&D expenditures.

Table 6. T-test equality of means: manufacturing *versus* services sector

Variables	Manuf.		Services		Diff Manuf. – Services	
	Mean	Std. Err.	Mean	Std. Err.		
Turnover per employee (€)	338,169	47,816	553,133	62,139	-214,964	***
Innovation (Yes/No)	0.454	0.006	0.336	0.006	0.118	***
Intangible investment per employee (€)	11,194	4,602	4,665	1,053	6,529	
R&D investment per employee (€)	5,872	2,659	1,422	678	4,449	
ICT investment per employee (€)	3,045	1,742	1,736	570	1,309	
New Skills investment per employee (€)	1,017	363.6	527	117.0	490	
Organiz. Improv. invest. per employee (€)	1,261	522	980	399	280	
Investing in Intangibles (Y/N)	0.851	0.004	0.836	0.005	0.015	**
Investing in R&D (Y/N)	0.401	0.006	0.169	0.005	0.232	***
Investing in ICT (Y/N)	0.652	0.006	0.648	0.006	0.004	
Investing in new skills (Y/N)	0.696	0.005	0.646	0.006	0.050	***
Investing in process improvements (Y/N)	0.362	0.006	0.309	0.006	0.054	***
N° of major obstacles	2.244	0.024	2.308	0.028	-0.064	*
Faced with a major obstacle (Y/N)	0.744	0.005	0.717	0.006	0.027	***
Obstacle: Demand for products or services	0.239	0.005	0.216	0.005	0.023	***
Obstacle: Availability of staff with the right skills	0.456	0.006	0.415	0.007	0.041	***
Obstacle: Energy costs	0.240	0.005	0.223	0.006	0.017	**
Obstacle: Access to digital infrastructure	0.082	0.003	0.105	0.004	-0.023	***
Obstacle: Labour market regulations	0.289	0.006	0.269	0.005	0.020	**
Obstacle: Business regulations and taxation	0.265	0.005	0.323	0.006	-0.058	***
Obstacle: Av. of adequate transport infrastr.	0.132	0.004	0.150	0.005	-0.018	***
Obstacle: Availability of finance	0.199	0.005	0.208	0.005	-0.009	
Obstacle: Uncertainty about the future	0.361	0.006	0.379	0.006	-0.017	**

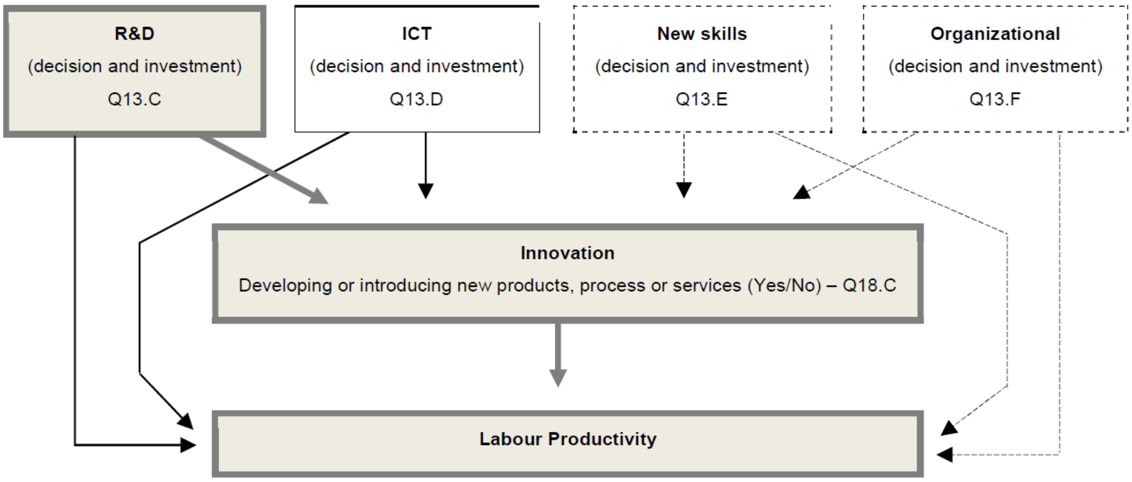
Source: Authors' own elaboration. Note: N° of observations: Manufacturing = 7,295 and Services = 5,635. Significance level: *** p<0.01, ** p<0.05, * p<0.1.

Nevertheless, manufacturing firms have a lower level of labour productivity than firms in the service sector (Table 6). Even if manufacturing has a higher intensity of investment in intangibles than other sectors, differences are not significant. The number of obstacles is slightly higher for firms in services, but manufacturing firms are more likely to face a major obstacle. There is no difference between sectors regarding the obstacle of the availability of finance. Demand for products or services, availability of staff with the right skills and energy costs hamper more the investment activities of manufacturing firms, whereas service firms emphasize the remaining obstacles (regulations, infrastructures and uncertainty).

4. Methodological framework

In order to assess investment's impact on innovation and productivity we use an augmented version of the **Crépon, Duguet and Mairesse** (1998) model (also called the CDM model). We model the demand for different types of intangible investments and relate them to innovation and labour productivity (**Figure 1**), considering the endogeneity of the investment choices in the presence of obstacles to investment. However, while the original CDM model assesses the effect of R&D (or intangible) investment on labour productivity indirectly through innovation, following **Polder et al.** (2009) and **Hall et al.** (2013) our methodological framework also explores the potential direct linkage between intangible investments and productivity, as illustrated in Figure 1 below.

Figure 1. Framework of the study: 3-step model



Source: Authors' own elaboration based on **Crépon et al.** (1998), **Polder et al.** (2009) and **Hall et al.** (2013).

Legend: Standard CDM model; Augmented version of the CDM proposed by **Polder et al.** (2009) and **Hall et al.** (2013); Aditional proposed augmented version of the CDM model in this study

Note: Q13.C, Q13.D, Q13.E, Q.13F and Q18.C refer to the EIBIS questions from where the information was taken. R&D also includes the acquisition of intellectual property. ICT comprises software, data, IT networks and website activities. The acquisition of new skills corresponds to the training of employees. Organizational refers to organization and business process improvements, such as restructuring and streamlining. Labour productivity is measured by turnover per employee. More information about the data source is available in Table A1 in the Appendix.

The investment-innovation-productivity relationship is estimated using two-stage least squares (2SLS). The first stage refers to the investment (**INV**) in R&D, ICT, new skills or organizational improvements, and includes an equation for each j category of intangible investment. Furthermore, due to possible selection bias of the investment intensity, a Heckman two-step approach (**Heckman, 1979**) is also used. In a first step, the probability of investing in intangible j is estimated (2). In a second step, the predicted inverse Mills ratio ($\widehat{\text{IMR}}$) is included in the equation explaining the investment intensity of j (3). In this second step, the sample is restricted to companies having positive investments. We measure investment intensity as the logarithm of investment expenditure per employee.

$$\begin{cases} \Pr\{INV_{j,i,t}\} = f(FC_{i,t}, MC_{i,t}, CAP_{i,t}, Z_{j,i,t}) & (2) \\ INV_{j,i,t} = f(\widehat{IMR}_{j,i,t}, FC_{i,t}, MC_{s,t}, CAP_{i,t}, OB_{i,t}) & (3) \end{cases}$$

where:

- $INV_{j,i,t}$: intangible investment j, with j = RD, ICT, new skills or organisational improvements.
- $FC_{i,t}$: firm characteristics
- $MC_{s,t}$: market conditions in sector s
- $Z_{j,i,t}$: percentage of firms in each industry-year investing in intangible j
- $\widehat{IMR}_{j,i,t}$: inverse Mills ratio
- $CAP_{i,t}$: production capacity
- $OB_{i,t}$: obstacles to investment activities in general

The second stage of our augmented CDM estimates the innovation (**INNO**) probability, considering the aim of firms' investment: developing or introducing new products, processes or services.[15] Innovation behaviour (4) is explained by the predicted value of intangible investments.

$$\Pr\{INNO_{j,i,t}\} = f(FC_{i,t}, TANG_{i,t}, \sum \widehat{INV}_{j,i,t}) \quad (4)$$

where:

- $FC_{i,t}$: firm characteristics
- $TANG_{i,t}$: non-intangible investment per employee
- $\sum \widehat{INV}_{j,i,t}$: sum of predicted value of intangible investment per employee

The third and last stage of our model refers to labour productivity (**LP**) equation (5), measured by the logarithm of turnover per employee, and includes the predicted values of innovation propensity and investment intensity.

$$LP_{i,t} = f(FC_{i,t}, K_{i,t}, \widehat{INNO}_{j,i,t}, \sum \widehat{INV}_{j,i,t}) \quad (5)$$

where:

- $FC_{i,t}$: firm characteristics
- $K_{i,t}$: capital stock per employee
- $\widehat{INNO}_{j,i,t}$: predicted value of innovation decision
- $\sum \widehat{INV}_{j,i,t}$: sum of predicted value of intangible investment per employee

[15] We constructed the binary variable based on question 18 of the EIBIS, which indicates the proportion of total investment destined to (A) replacing capacity, (B) expanding capacity and/or (C) developing or introducing new products, processes or services. Then, if the firm used part or all of the investment for developing or introducing new products, processes or services the variable INNO assumes the value of 1 and 0 otherwise.

The probability equations (2) and (4) are estimated using a Probit model, whereas investment intensity and labour productivity are estimated using ordinary least squares. We have an unbalanced panel where most firms only answer once to the EIBIS: in other words, the model is estimated using repeated cross-sectional data.

All equations (2, 3, 4 and 5) include a set of typical firm characteristics (**FC**), namely firm size (measured by the logarithm of the number of employees), age, ownership (belonging to a group), exporter status, country, sector[16] and year dummies. The level of competition (industry-year indicator) is included as a variable to control for market conditions (**MC**) able to influence the decision (3) and the intensity of investment (4). Competition level is estimated using the Herfindahl and Hirschman Index (HHI) at the NACE 4-digit level. In investment equations (3) and (4) we also include an indicator variable taking value 1 (and 0 otherwise) if the firm is operating above maximum capacity (**CAP**) regarding the use of machines and equipment.[17]

Following **Álvarez** (2016), as exclusion restriction (**Z**) we include the percentage of firms in the industry-year that invest in intangible j and excluding the firm i decision. Doing so, we have a specific and different exclusion restriction for each intangible investment category. In the equation on the investment decision in new skills, we also include a proxy for sectorial labour force qualifications, estimated by the average industry-year wages per employee. Since certain sectors require more qualified workers than others, this is likely to impact the decision to invest in employee training/acquisition of new skills.

Obstacles to investment activities[18] (**OB**) include: (A) demand for products or services; (B) availability of staff with the right skills; (C) Energy costs; (D) Access to digital infrastructure; (E) Labour market regulations; (F) Business regulations (e.g. licences, permits, bankruptcy) and taxation; (G) Availability of adequate transport infrastructure; (H) Availability of finance; (I) Uncertainty about the future. They are only included in the investment intensity equation (3) in order to correct for any potential bias, as reported in Section 2. Indeed, obstacles are likely to have a positive effect on the probability to invest since firms that invest are more likely to feel the obstacles than firms that do not invest. Firms that invest will give higher scores to the obstacles they perceive, while firms that do not invest are perhaps not even aware of the obstacles. Hence the strategy used by **Savignac** (2008) and **D'Este et al.** (2012) is to eliminate firms that would not have invested anyway, irrespective of how they feel about the obstacles. That eliminates a potential source of positive bias in the coefficient of the obstacle variables. After eliminating firms that do not invest at all, the estimated coefficient on the obstacles in the investment equation is still positive. This suggests that investing firms are more likely to perceive obstacles as important. The deterring factors of obstacles to investment are also more likely to be visible in the intensity of investment. If a firm has decided to invest despite all the obstacles it knows it faces, it will invest more or less depending on the importance of the obstacles.

[16] The regression estimations include four categories of sectors extracted from EIBIS: manufacturing, construction, services and infrastructure.

[17] This information comes from question 12 of EIBIS: *Was your company operating at its maximum capacity attainable under normal conditions?* The answers include four categories: 1) above maximum capacity; 2) at maximum capacity; 3) somewhat below full capacity; 4) substantially below full capacity. The CAP variable assumes the value of 1 if the firm said it was above maximum capacity and 0 otherwise.

[18] This information comes from question 38 of EIBIS, where firms surveyed reported if these are: 1) a major obstacle; 2) a minor obstacle; 3) not an obstacle at all. The obstacle variables assume the value of 1 if the firm is faced with a major obstacle and 0 otherwise. Therefore, the perception about obstacles is general and not specific to each category of investment.

The innovation equation[19] (4), in addition to intangible investments, also comprises the amount of non-intangible ones, such as land, business buildings, infrastructure, machinery and equipment.

In turn, variables entering the productivity equation (5) are labour (firm size), physical capital stock (proxied by tangible fixed assets at the beginning of the period) and intangibles investment as proxies for stock of intangibles.[20] The intensity of investment in intangibles corresponds to the predicted value for all firms in the sample. Following **Hall et al.** (2013), we do not restrict estimation of the innovation and productivity equations to intangible-performing firms.

When we include all four categories of intangibles in the same equations, the high levels of correlation between their predicted values does not provide stable results. Instead, we estimate one equation for each intangible and include the remainder of total intangible investment together as a single variable (for more details see Figure A1 in Appendix).

[19] A limitation of our innovation variable is being only related with investment activities (flows and not stocks). Indeed, firms can introduce a new product or services in the market without making any investment, but we believe this happens less frequently.

[20] Indeed, due to the characteristics of our sample, mainly composed of firms that answered one survey, estimating the stock of intangibles using the Perpetual Inventory Method (PIM) is not recommended due to the short period of time (only one year). However, to check robustness, we also estimated the intangible stock for a sub-sample of firms and the results, available upon request, seem to indicate that the flows of intangibles are a good proxy for stocks.

5. Results and discussion

5.1. Investment equations

Table 7 reports the results of the first step of our model with the probability of investing in each intangible investment j as the dependent variable. In all the equations, the sector-year indicator of the percentage of firms investing in intangible j has a significant effect on the investment decision, implying that our exclusion restrictions are relevant in explaining the different investment decisions. This means that the decision of firm i in year t to invest in intangible j depends on market trends. The higher the number of firms in the same sector investing in intangible j, the more firm i will tend to invest in it.

Table 7. Results of Probit regression: Y = Investing in intangible *j*

Variables	*j* = Total intangible (1)		*j* = R&D (2)		*j* = ICT (3)		*j* = New skills (4)		*j* = Organiz. (5)	
% of firms investing in *j* (1)	1.758	***	2.035	***	1.282	***	1.136	***	0.319	*
	(0.181)		(0.090)		(0.133)		(0.152)		(0.193)	
Average wage per employee	-		-		-		0.0381		-	
in the sector (2)	-		-		-		(0.027)		-	
Log(n° employees)	0.476	***	0.114	***	0.301	***	0.731	***	0.298	***
	(0.035)		(0.030)		(0.030)		(0.028)		(0.027)	
Log(n° employees) – Squared	-0.032	***	0.003		-0.016	***	-0.064	***	-0.017	***
	(0.004)		(0.003)		(0.003)		(0.003)		(0.003)	
Belonging to a group (Y/N)	-0.016		-0.090	***	-0.172	***	0.030		-0.075	***
	(0.027)		(0.023)		(0.021)		(0.022)		(0.021)	
Exporter (Y/N)	0.203	***	0.436	***	0.223	***	0.098	***	0.193	***
	(0.023)		(0.022)		(0.019)		(0.020)		(0.020)	
Above maximum capacity (Y/N)	0.133	***	0.093	**	0.110	***	0.083	**	0.162	***
	(0.050)		(0.041)		(0.039)		(0.041)		(0.038)	
Competition	-1.318	***	0.660		-0.039		-0.487		-0.147	
	(0.506)		(0.438)		(0.402)		(0.425)		(0.395)	
Competition – Squared	0.755	**	-0.561	*	-0.085		0.242		0.109	
	(0.357)		(0.313)		(0.287)		(0.302)		(0.283)	
Age: 0-5 years	-0.044		0.082		-0.048		-0.036		0.040	
	(0.049)		(0.052)		(0.044)		(0.045)		(0.046)	
Age: 5-9 years	0.048		0.084	**	-0.024		0.000		0.103	***
	(0.034)		(0.033)		(0.029)		(0.030)		(0.030)	
Age: 10-19 years	0.015		0.007		-0.037	*	0.009		0.029	
	(0.024)		(0.023)		(0.020)		(0.021)		(0.021)	
Year, sector and country dummy	YES		YES		YES		YES		YES	
Constant	-1.356	***	-2.061	***	-1.291	***	-2.318	***	-1.533	***
	(0.231)		(0.170)		(0.173)		(0.315)		(0.166)	
N° of observations	24,126		24,126		24,126		24,126		24,126	
Log pseudolikelihood	-9,585.1		-11,400.8		-14,664.3		-13,524.3		-14,102.7	
Pseudo R2	0.111		0.151		0.079		0.098		0.061	
Wald test - H0: All coefficients = 0	0.000		0.000		0.000		0.000		0.000	
% Correctly classified	83.88%		78.30%		67.67%		71.77%		69.48%	

Note: Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Results of Wald test refer to p-value. (1) Different in each equation and estimated at NACE 2-digits. (2) Refers to the mean log wage per employee in the NACE 2-digit sector. Reference category for age is more than 20 years.

Table 8 shows the results of OLS regressions for investment intensity of each intangible j, including the Inverse Mills Ratio (IMR) estimated in the previous stage as explanatory variable. Since we only run the regression only for the sub-sample of firms that invest in intangible j, we need to correct for any potential selection bias by including the IMR. The results of Table 8 show that, except for organizational improvement (column 5), the IMR is always significant, confirming our suspicion of a correlation between the error terms in the selection and the intensity equations and hence the need to correct for selection bias. The negative value of the IMR indicates that the higher the error term in the selection equation[21] the lower the error term in the intensity equation will be.

Table 8. Results of OLS regression, intensity of investment: Y = Log(investment in *j* per employee)

Variables	*j* = Total Intangible		*j* = R&D		*j* = ICT		*j* = New skills		*j* = Organiz.	
	(1)		(2)		(3)		(4)		(5)	
Inverse Mills Ratio - (invest. j) *	-2.993	***	-2.423	***	-3.723	***	-1.581	***	-1.208	
	(0.251)		(0.144)		(0.253)		(0.205)		(1.177)	
Log(n° employees)	-1.086	***	-1.001	***	-1.298	***	-1.161	***	-1.153	***
	(0.058)		(0.070)		(0.057)		(0.084)		(0.261)	
Log(n° employees) – Squared	0.089	***	0.055	***	0.090	***	0.097	***	0.082	***
	(0.005)		(0.007)		(0.004)		(0.007)		(0.016)	
Belonging to a group (Y/N)	0.198	***	0.264	***	0.499	***	0.229	***	0.308	***
	(0.028)		(0.052)		(0.035)		(0.024)		(0.072)	
Being an exporter (Y/N)	0.372	***	-0.221	***	-0.104	**	0.184	***	0.054	
	(0.032)		(0.078)		(0.041)		(0.025)		(0.169)	
Above maximum capacity (Y/N)	0.017		-0.047		-0.135	***	0.011		-0.229	
	(0.050)		(0.093)		(0.051)		(0.042)		(0.149)	
Competition	2.395	***	-0.656		1.108	**	0.662		1.214	
	(0.540)		(1.069)		(0.547)		(0.464)		(0.768)	
Competition – Squared	-1.916	***	0.550		-0.793	**	-0.686	**	-1.187	**
	(0.384)		(0.756)		(0.391)		(0.330)		(0.553)	
Obstacle: Demand	0.005		0.046		-0.028		0.003		-0.060	
	(0.029)		(0.053)		(0.029)		(0.025)		(0.045)	
Obstacle: Staff with the right skills	0.071	***	-0.014		0.035		0.101	***	-0.016	
	(0.024)		(0.046)		(0.024)		(0.020)		(0.038)	
Obstacle: Energy costs	-0.134	***	-0.249	***	-0.114	***	-0.101	***	-0.017	
	(0.030)		(0.059)		(0.031)		(0.026)		(0.049)	
Obstacle: Digital infrastructure	0.226	***	0.085		0.206	***	0.103	***	0.093	
	(0.042)		(0.078)		(0.042)		(0.036)		(0.067)	
Obstacle: Labour market regul.	-0.060	**	-0.038		-0.092	***	-0.020		-0.049	
	(0.028)		(0.052)		(0.028)		(0.024)		(0.044)	
Obstacle: Business regulations	0.110	***	0.086		0.072	**	0.032		-0.087	*
	(0.028)		(0.052)		(0.028)		(0.024)		(0.045)	
Obstacle: Transport infrastructure	0.005		0.007		0.042		0.025		0.053	
	(0.035)		(0.068)		(0.035)		(0.030)		(0.054)	
Obstacle: Availability of finance	-0.010		0.051		-0.065	**	-0.058	***	0.018	
	(0.030)		(0.056)		(0.030)		(0.026)		(0.048)	
Obstacle: Uncertainty	-0.075	***	-0.045		-0.068	*	-0.047	***	0.061	
	(0.026)		(0.051)		(0.027)		(0.023)		(0.043)	
Age dummy	YES		YES		YES		YES		YES	
Year, sector and country dummy	YES		YES		YES		YES		YES	
Constant	10.086	***	13.547	***	11.611	***	9.212	***	10.886	***
	(0.266)		(0.493)		(0.327)		(0.332)		(2.167)	

[21] A higher error term in the selection equation is associated with a higher probability of being selected and vice versa.

N° of observations	20,162	5,904	15,151	16,573	7,575
R-Squared	0.2533	0.2913	0.2743	0.3021	0.1953
Wald test - H0: All coefficients = 0	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Results of Wald test refer to the p-value. Regressions only include firms that invested in each category j. Reference category for major obstacles it is minor or not an obstacle at all.

Regarding the effect of obstacles on investment intensity, Table 8 shows that some obstacles have a negative effect and others a positive one, which lets us distinguish between *deterring* and *revealed* barriers to investment activities. On average, obstacles related to energy costs, access to finance, uncertainty about the future and labour market regulations affect investment intensity negatively. Others (such as the availability of staff with the right skills, access to digital infrastructure and business regulation) seem to be more associated with *revealed* obstacles as the result of “learning from experience” in investing. It is also interesting to see that the perception of access to digital infrastructure as an obstacle to investment activities seems to be more associated with ICT investment, whereas the availability of staff with the right skills is more associated with the acquisition of new skills.

The negative effects of access to finance and uncertainty about the future on investment intensity are in line with the findings of **D’Este et al.** (2012). Indeed, without funding, firms are not able to invest and with market or political uncertainty, firms may be reluctant to invest more. Turning to the effect of energy costs, if we consider that they can include both the production and consumption of energy, the negative effect on investment could be associated either with the cost of investment or with the additional cost of energy (e.g. electricity and fuel) resulting from the investment. An example of the former could be the high R&D cost of developing new energy technology. The latter could be associated with an increase in electricity consumption as the result of ICT investment, as demonstrated by **Cho et al.** (2007). Lastly, the *deterring* effect of labour market regulations on intangible investment could be due to an increase in adjustment costs, as the result of employment protection legislation, which may lead to underinvestment in activities that require adjustment, as suggested by **Griffith and Macartney** (2014).

Furthermore, the results in Table 8 suggest that once the firm takes the decision to invest, the intensity of some of the intangible investments is more affected by some obstacles than others. This is particularly the case of ICT investment and the acquisition of new skills, where respectively six and five of all obstacles are significant, whereas the investment in R&D and organizational improvements is only significantly impacted by one obstacle. This suggests that firms face most barriers for investment in ICT and the acquisition of new skills.

The different control variables have the expected effect. Firm size positively influences the decision to invest and negatively the intensity. However, only until a threshold, where the situation is reversed (inverted U and U-shape relationship). The positive size’ effect for the selection equation and the negative one for the intensity equation is often reported in the literature. Indeed, when size increases the denominator related to efficiency also increases and probably faster than the numerator, and as a result the intensity decreases. To be above maximum capacity utilization only has a positive and significant effect on the decision to invest for total intangibles. On average, belonging to a group has a negative and significant effect on the decision to invest but a positive one on intensity. Being an exporter has a positive effect on the decision to invest for total intangibles, but its effect on intensity seems to be different for each category: negative for R&D and process improvement and positive for ICT.

5.2. Innovation equation

After the investment step, our conceptual model includes the innovation equation. Table 9 reports the results of the Probit regression regarding the probability of innovating and includes the predicted value of intangible investments as an explanatory variable.

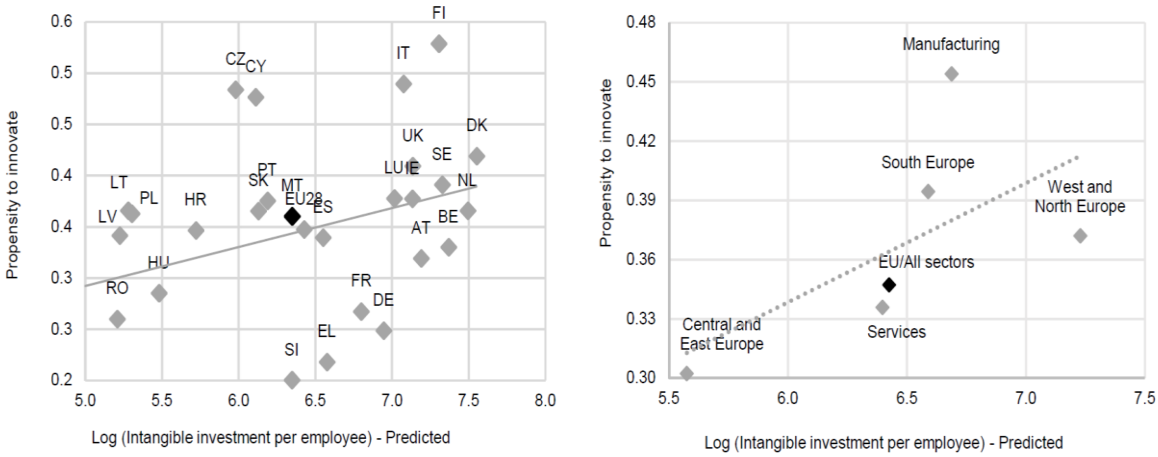
Table 9. Results of Probit regression for innovation behaviour, by European regions and sectors

Variables	All firms	By European regions			By sectors	
		Central and East	South	West and North	Manuf.	Services
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted intangible investment	0.480 ***	0.432 ***	0.539 ***	0.762 ***	0.444 ***	0.167 *
per employee – Log	(0.045)	(0.064)	(0.103)	(0.084)	(0.079)	(0.090)
Log (Tangible investment	0.011 **	0.030 ***	0.022 *	-0.006	0.039 ***	0.027 **
per employee)	(0.006)	(0.009	(0.012)	(0.009)	(0.010)	(0.012)
No investment in tangible	-0.338 ***	-0.354 ***	-0.354 ***	-0.315 ***	-0.246 **	-0.251 **
(Yes/No)	(0.050)	(0.080	(0.112)	(0.080)	(0.098)	(0.104)
Log(n° employees)	0.242 ***	0.067	0.237 ***	0.574 ***	0.135 *	0.039
	(0.037)	(0.057	(0.081)	(0.068)	(0.072)	(0.075)
Log(n° employees) – Squared	-0.014 ***	0.000	-0.014 *	-0.042 ***	-0.001	0.004
	(0.004)	(0.006	(0.008)	(0.007)	(0.007)	(0.008)
Age: 0-5 years	0.041	0.057	-0.057	0.026	-0.091	-0.047
	(0.047)	(0.069	(0.133)	(0.073)	(0.095)	(0.101)
Age: 5-9 years	0.057 *	0.031	-0.063	0.079	-0.042	0.138 **
	(0.031)	(0.044	(0.082)	(0.051)	(0.062)	(0.065)
Age: 10-19 years	0.068 ***	0.025	0.054	0.119 ***	-0.032	0.111 **
	(0.021)	(0.032	(0.049)	(0.035)	(0.039)	(0.043)
Belonging in a group (Y/N)	-0.103 ***	-0.058	-0.139 **	-0.198 ***	-0.118 ***	-0.113 **
	(0.023)	(0.041	(0.055)	(0.035)	(0.039)	(0.048)
Being exporter (Y/N)	0.023	-0.011	-0.028	-0.080	0.047	0.199 **
	(0.033)	(0.050	(0.078)	(0.057)	(0.066)	(0.067)
Year, sector and country dummy	YES	YES	YES	YES	YES	YES
Constant	-4.593 ***	-3.232 ***	-3.935 ***	-7.374 ***	-4.412 ***	-2.323 ***
	(0.378)	(0.401)	(0.769)	(0.726)	(0.670)	(0.746)
N° of observations	24,126	10,013	4,386	9,727	7,295	5,635
Log pseudolikelihood	-14,366.9	-5,637.7	-2,688.8	-5,969.1	-4,671.0	-3,365.3
Pseudo R2	0.0777	0.0812	0.0860	0.0703	0.071	0.0642
Wald test H0: All coefficients = 0	0.0000	0.0000	0.0000	0.000	0.000	0.000
Marginal effect intangible investment per employee	0.163 ***	0.138 ***	0.188 ***	0.267 ***	0.163 ***	0.057 *

Note: Innovation behaviour corresponds to the aim of firms' investment: developing or introducing new products, processes or services. Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Results of the Wald test and Z-test refer to p-value.

As expected, the intensity of intangible investment has a positive and significant effect on the likelihood to innovate. This finding can be observed in all the specifications reported in Table 8: EU28 (column 1), different European regions (columns 2, 3 and 4) and different sectors (columns 5 and 6). The magnitudes of the marginal effects seem to be very similar between Central and East Europe and South Europe. Furthermore, the Z-test confirms that no statistical differences between them exist.[22] However, the marginal effect of intangible investment in West and North Europe seems to be higher and statistically different than that of other regions. Concerning the differences between sectors, we can observe at a 5% significance level[23] that the marginal effect of intangible investments on innovation propensity is higher in the manufacturing sector than in services (0.16 versus 0.06, respectively). This finding is also confirmed by the positioning of each sector on the investment-innovation relationship reported in Figure 3, where for similar value of investment (6.7 and 6.4) firms operating in manufacturing sector report a higher propensity to innovate than that on services one (0.45 versus 0.34).

Figure 3. Intangible investment-innovation relationship



Note: Values refer to Europe regions or sectors average.

Regarding the individual effect of each intangible category, Table 10 presents the results of the Probit regression including as explanatory variable the predicted value of intangible j and the predicted value of the remaining intangible investments. The results show that only R&D and ICT investments have a positive and significant effect on the probability of developing or introducing new products, processes or services. The acquisition of new skills, through employee training, seems to have no significant effect. In turn, organizational and business process improvements appear to harm innovation behaviour. Taking into account that the reference category of the dependent variable is to invest for replacing fixed assets or expansion of existing capacity, this could mean that organizational and business process improvements

[22] Results of Z-test (p-value): CEE versus WNE= 0.002; CEE versus SE = 0.376; WNE versus SE = 0.094. The z-test was estimated on the basis of the same methodology used by **Clogg et al.** (1995): $Z = \beta_1 - \beta_2 / \sqrt{(Std.Error\ \beta_1)^2 + (Std.Error\ \beta_2)^2}$.

[23] Results of Z-test (p-value): manufacturing versus services= 0.021.

(and possibly also new skills) are more associated with replacement and expansion rather than the development of something new. Furthermore, results for other intangible investment in column (3) and (4), which includes R&D and ICT, reveal to be more important to explain innovation than the effect of investment in new skills and organizational improvements. Indeed the coefficient of other intangible investment in column (3) and (4) is always positive, whereas, that of investment in new skills is non-significant and that of organizational improvements is negative.

Table 10. Results of Probit regression model for innovation behaviour, by intangible investment categories

Variables	*j* = R&D (1)		*j* = ICT (2)		*j* = New skills (3)		*j* = Organiz. (4)	
Predicted Intangible investment	0.353	***	0.336	***	-0.082		-0.260	***
in *j* per employee - Log	(0.025)		(0.057)		(0.094)		(0.096)	
Predicted remaining intangible	0.227	***	0.233	***	0.482	***	0.441	***
investment per employee - Log	(0.069)		(0.064		(0.044)		(0.043)	
Log (Tangible investment	0.016	***	0.012	**	0.014	**	0.012	**
per employee)	(0.006)		(0.006)		(0.006)		(0.006)	
No investment in tangible (Yes/No)	-0.326	***	-0.338	***	-0.329	***	-0.333	***
	(0.050)		(0.050)		(0.050)		(0.050)	
Firms characteristics	YES		YES		YES		YES	
Year, sector and country dummy	YES		YES		YES		YES	
Constant	-5.703	***	-5.102	***	-4.186	***	-1.925	**
	(0.509)		(0.372)		(0.488)		(0.795)	
N° of observations	24,126		24,126		24,126		24,126	
Log pseudolikelihood	-14,282.9		-14,340.0		-14,315.9		-14,369.9	
Pseudo R2	0.0831		0.0795		0.081		0.0775	
Wald test - H0: All coefficients = 0	0.0000		0.0000		0.0000		0.0000	
Marginal effect intangible investment *j* per employee	0.1189	***	0.1135	***	-0.0276		-0.0883	***

Note: Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05. Results of Wald test refer to p-value. Firms characteristics include size (n° of employees), age, belonging in a group (Yes/No) and being exporter (Yes/No). Innovation behaviour corresponds to the aim of firms' investment: developing or introducing new products, processes or services.

The different control variables have the expected effect. Larger firms and those with experience in foreign markets have a higher probability of innovating, whereas older firms (more than 20 years old) and those belonging to a group have a lower tendency. This negative effect of ownership was also found by **Alvarez** (2016), who explained this by spillover effects and economies of scale. Indeed, knowledge flows easier between different branches of a group.

5.3. Labour productivity equation

The last stage of the model refers to the labour productivity equation and includes as main explanatory variables the predicted value of the innovation decision and the predicted value of intangible investments.

In this way and following **Hall et al.** (2013) we are able to test if intangible investments affect labour productivity only indirectly, through innovation, or also directly. The results reported in column (1) of Table 11 reveal a positive effect of both innovation and intangible investments on labour productivity, confirming our hypothesis that intangible investments can enhance productivity without innovation.

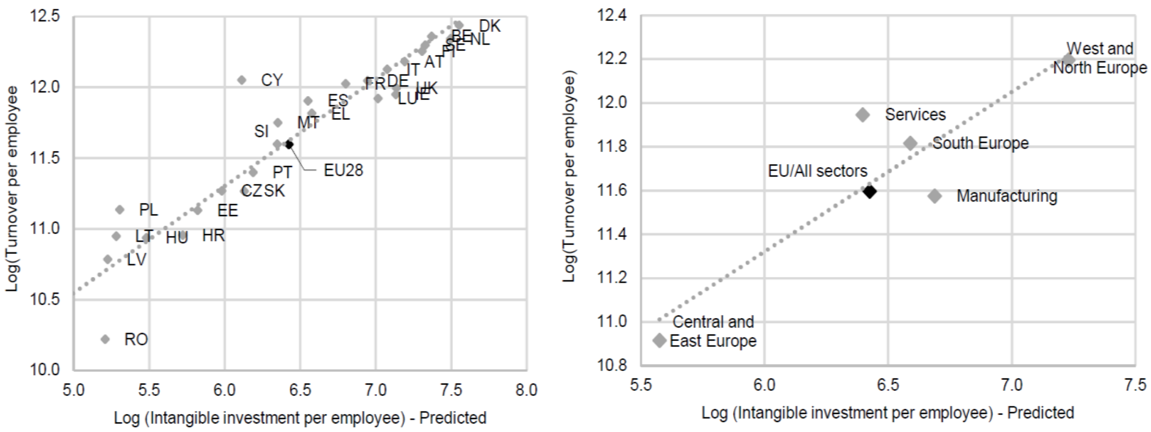
Table 11. Results of labour productivity equation (OLS), by European regions and sectors: Y = Log(turnover per employee)

Variables	All firms	By European regions			By sectors	
		Central and East	South	West and North	Manuf.	Services
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted value - Innovation	0.095 **	0.187 **	0.238 **	-0.073	0.575 ***	-0.151 *
	(0.046)	(0.074)	(0.106)	(0.071)	(0.085)	(0.091)
Predicted Intangible investment	0.358 ***	0.318 ***	0.249 **	0.427 ***	0.117 *	0.806 ***
per employee - Log	(0.044)	(0.069)	(0.104)	(0.072)	(0.071)	(0.087)
Log(Stock capital per employee)	0.112 ***	0.145 ***	0.118 ***	0.081 ***	0.152 ***	0.093 ***
	(0.005)	(0.007)	(0.011)	(0.007)	(0.011)	(0.009)
Log(n° employees)	0.289 ***	0.242 ***	0.236 ***	0.348 ***	0.135 **	0.581 ***
	(0.037)	(0.075)	(0.078)	(0.058)	(0.062)	(0.075)
Log(n° employees) - Squared	-0.033 ***	-0.032 ***	-0.032 ***	-0.034 ***	-0.019 ***	-0.064 ***
	(0.004)	(0.009)	(0.008)	(0.006)	(0.006)	(0.008)
Age: 0-5 years	-0.165 ***	-0.186 ***	0.033	-0.154 **	-0.131 **	-0.251 **
	(0.039)	(0.057)	(0.110)	(0.060)	(0.063)	(0.105)
Age: 5-9 years	-0.149 ***	-0.085 **	-0.179 **	-0.221 ***	-0.117 **	-0.293 ***
	(0.026)	(0.038)	(0.074)	(0.042)	(0.053)	(0.058)
Age: 10-19 years	-0.034 **	-0.033	-0.043	-0.033	-0.004	-0.083 **
	(0.017)	(0.025)	(0.042)	(0.028)	(0.030)	(0.039)
Belonging in a group (Y/N)	0.293 ***	0.395 ***	0.245 ***	0.236 ***	0.287 ***	0.223 ***
	(0.020)	(0.038)	(0.050)	(0.029)	(0.031)	(0.044)
Being exporter (Y/N)	0.185 ***	0.251 ***	0.203 ***	0.112 ***	0.025	0.210 ***
	(0.028)	(0.044)	(0.064)	(0.045)	(0.050)	(0.057)
Year, sector and country dummy	YES	YES	YES	YES	YES	YES
Constant	7.501 ***	6.602 ***	8.484 ***	7.147 ***	9.623 ***	4.289 ***
	(0.387)	(0.461)	(0.789)	(0.645)	(0.637)	(0.768)
N° of observations	24,126	10,013	4,386	9,727	7,295	5,635
R-Squared	0.360	0.283	0.177	0.122	0.423	0.313
Wald test - H0: All coefficients = 0	0.000	0.000	0.000	0.000	0.000	0.000

Note: Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Results of Wald test refer to p-value.

Regarding the effect of innovation and intangible investments on labour productivity in different European regions, columns (2) to (4) in Table 11 show a positive and significant impact, both in Central and East Europe, as well as in South Europe. In West and North Europe, the direct effect of intangibles is more important in explaining increases in productivity than innovation. If both variables are included in the estimation, the effect of innovation disappears. The Z-test results reveal that no statistical differences between regions exist concerning the elasticities of intangible investments.[24] As we can see in Figure 4 the relationship between intangible investment and productivity seems to be strictly linear, which confirms the existence of similar elasticities between regions. As for Figure 3 (investment-innovation relationship), we observe on Figure 4 that firms located in West and North Europe have the highest performance in both intangible investment and productivity level, whereas that in Central and East Europe have the lowest value of input and output.

Figure 4. Intangible investment-productivity relationship



Note: Values refer to Europe regions or sectors average.

Columns (5) and (6) of Table 11 show that intangible investment has a positive and significant effect on productivity performance, both in manufacturing and services. Nevertheless, the coefficient, which corresponds to the elasticity, in the services sector is higher than in manufacturing and they are statistically different.[25] In turn, innovation only has a positive effect in manufacturing, whereas in the services sector we find a negative effect but only at a 10% level of significance. All these findings suggest that intangible investments have a direct and indirect effect on productivity in the manufacturing sector, while only a direct effect seems to prevail in services. The negative effect of innovation in the service sector could be due to several factors. In the descriptive statistics in Section 3, manufacturing firms have a higher propensity to innovate than services. The negative effect suggests that in the services sector investing with the aim to replace fixed assets or expanding firm capacity (reference category for innovation behaviour) is more able to explain increases in productivity than to invest for developing or introducing a new service. Furthermore, from Figure 4 we can observe that firms in the manufacturing sector that perform less well regarding productivity level face to a higher value of intangible investment.

Turning to the analysis of the individual effect of each intangible category on productivity, Table 12 shows the results of the OLS regressions including the predicted value of intangible *j* and of the remaining amount of intangible investments as explanatory variables. Results show that innovation behaviour and all types of intangible investments have a positive effect on labour productivity. However, it seems that investment in ICT and new skills are more important explaining productivity gains than other intangibles.

[24] Results of z-test (p-value): CEE versus WNE : 0.272; CEE versus SE = 0.581; WNE versus SE = 0.157.
[25] Results of z-test (p-value): manufacturing versus services= 0.000

Indeed, results reported in columns (2) and (3) show that the effect of others intangible investments, which include R&D and organizational improvements, are negative and significant or non-significant, when included in the same regression with ICT or new skills, respectively. These results confirm the importance of skills to enhance productivity, as suggested by **Díaz-Chao et al.** (2015), as well as the importance of ICT on productivity as argued by **Hall et al.** (2013).

Table 12. Results of labour productivity equation (OLS), by intangible investment categories: Y = Log(turnover per employee)

Variables	*j* = R&D (1)		*j* = ICT (2)		*j* = New skills (3)		*j* = Organiz. (4)	
Predicted value – Innovation	0.137	***	0.128	***	0.116	***	0.107	**
	(0.044)		(0.045)		(0.045)		(0.046)	
Predicted Intangible investment in *j*	0.046	*	0.505	***	0.592	***	0.252	***
per employee - Log	(0.025)		(0.047)		(0.078)		(0.081)	
Predicted remaining intangible investment	0.458	***	-0.138	**	0.067		0.307	***
per employee - Log	(0.058)		(0.054)		(0.041)		(0.041)	
Log(Stock capital per employee)	0.112	***	0.112	***	0.111	***	0.111	***
	(0.005)		(0.005)		(0.005)		(0.005)	
Firms characteristics	YES		YES		YES		YES	
Year, sector and country dummy	YES		YES		YES		YES	
Constant	6.459	***	7.680	***	5.820	***	5.798	***
	(0.497)		(0.392)		(0.451)		(0.666)	
N° of observations	24,126		24,126		24,126		24,126	
R-Squared	0.360		0.363		0.362		0.361	
Wald test - H0: All coefficients = 0	0.000		0.000		0.000		0.000	

Note: Robust standard errors in parentheses. Significance level: *** p<0.01, ** p<0.05, * p<0.1. Results of Wald test refer to p-value. Firms characteristics include size (n° of employees), age, belonging in a group (Yes/No) and being exporter (Yes/No).

Finally, looking at the effect of our control variables, the results are line with the literature. Larger and older firms, as well as belonging to a group and exporting have a positive effect on labour productivity, revealing that any factor influencing economies of scale can enhance productivity.

6. Conclusion

Recent trends in the economy, transforming local to global scale thanks to digitalisation are raising several challenges for growth policy design. R&D, ICT and training of the work force are in the core of current European policies and to meet the challenges for the next decade, structural reforms are also needed (**ESPAS, 2015**). Understanding the way in which different intangible investments impact on productivity seems to be particularly useful for policymakers.

The present paper assessed the effect of several intangible investments on productivity using for the first-time data from the EIB Investment Survey (EIBIS) covering all 28 EU Member states during the period 2015-2017. We use an augmented and modified version of the CDM model to asset the link between investment, innovation and productivity and to answer to the following research questions: a) *How intangible investments affect productivity?* b) *Which intangible investments category contributes most to productivity gains?* c) *Is the productivity of manufacturing firms differently affected by intangible investments than that of services ones?* d) *In which EU region can companies expect a higher productivity return of their intangible investments?* Our results show that intangible investments can affect labour productivity directly and indirectly through innovation. The effect of intangible investments on innovation and productivity seems not to be different across different EU regions. Differences in terms of impact are more visible across sectors. In the manufacturing sector the effect of intangibles on productivity appears to be more indirect (through innovation), whereas in services this affects productivity more directly.

R&D investment seems to be more associated with innovation than productivity and its effect on productivity is less important in comparison with ICT and new skills. In turn, ICT investment has a decisive effect on both the propensity to innovate and productivity gains. This is in line with **Hall et al.** (2013) who argue that ICT can be a better predictor of productivity gains than innovation. The importance of ICT in achieving higher performance could also be symptomatic of changes in the economy, marked by a focus on the digital era.

In turn, the acquisition of new skills seems to be particularly important for increased productivity, in line with **Díaz-Chao et al.** (2015) who found that wages, a proxy of labour force qualifications and skills, is the main direct determinant of labour productivity. Furthermore, this conclusion also confirms the recommendations of **ESPAS** (2015) report, which highlighted that to prevent growing skills mismatches and the consequent exclusion of older workers from the labour market, a life-long training policy could aim to enhance labour force operation.

However, despite the contribution of ICT to innovation and productivity and of new skills acquisition to productivity, their investment intensities are facing the highest number of obstacles. For both, obstacles related to energy costs, access to finance and uncertainty negatively affect their investment intensity, which points towards the need for a more supportive ecosystem.

Findings of this research seem to bring new contributions to design more effective policy instrument. Even if R&D investment is important to enhance innovation, for achieving higher productivity levels, other factors and conditions are also needed. European policies should focus more on supporting investment in ICT and the acquisition of new skills to enhance productivity growth, and to ensure higher competitiveness.

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Appendix

Figure A1. Framework of the study

Model 1	Model 2	Model 3	Model 4	Model 5
Total Intangibles (*) + Control variables	R&D (*) + Other intangibles but R&D (*) + Control variables	ICT (*) + Other intangibles but ICT (*) + Control variables	New skills (*) + Other intangibles but new skills (*) + Control variables	Organizational improvements (*) + Other intangibles but organizational improvements (*) + Control variables
⬇	⬇	⬇	⬇	⬇
Innovation or Productivity	Innovation or Productivity	Innovation or Productivity	Innovation or Productivity	Innovation or Productivity

Note: (*) corresponds to the predicted value expressed per employee (intensity of investment). Control variables in the innovation equation include tangible investment, firm size, age, exporter status, ownership, year, sector and country dummies. Control variables in the productivity equation include physical capital stock, firm size, age, export status, ownership, year, sector and country dummies.

Table A1. Source of each variable

Variables	Source
Intangible decision and investment (R&D, ICT, new skills and organisational improvements)	Answer to Q13.C, Q13.D, Q13.E and Q.13F of EIBIS
Innovation behaviour	Answer to Q18.C of EIBIS
Labour productivity (turnover per employee)	Turnover from EIBIS. N° of employees from ORBIS (and EIBIS for missing value in ORBIS)
Percentage of firms in each industry-year investing in intangible	Estimated based on data from Q13.C, Q13.D, Q13.E and Q.13F of EIBIS
Obstacles to investment activities	Answers to Q38 of EIBIS
Tangible fixed assets (capital stock)	ORBIS
Tangible investment	Answer to Q13.A and Q13.B of EIBIS
Firm size (N° of employees)	ORBIS and EIBIS for missing value in ORBIS
Industry-year wages per employee	Estimated based on data from ORBIS
Production capacity	Answer to Q12 of EIBIS
Competition level	Estimated based on turnover data from EIBIS.
Age	Answer to Q1 of EIBIS
Export status	Answer to Q43.A. of EIBIS
Ownership	Answer to Q5 of EIBIS

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