Deliverable 7.3

IMPACT OF PUBLIC SECTOR INTANGIBLES:

Impact of public sector intangibles and their components on firms' productivity

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1. Introduction

Since the seminal paper of Aschauer (1989), much effort has been spent in the literature to evaluate the effects of public capital on private productivity. The hypothesis that the decrease in public expenditure can explain at least in part the downturn in productivity growth in the US in the 70s is generally accepted and corroborated by the subsequent recovery when also public investment increased. Recently, the debate has become more central with many countries that have cut their public expenditure after the economic crisis, under the belief that in times of crisis it is more important to keep the government debt under control. However, the expansionary effect of these austerity policies has been questioned by many scholars in the literature (Guajardo et al., 2014; Jordà and Taylor, 2016). In general, there is a trade-off between the positive effects of signaling financial markets a good solvency situation when keeping public debt low and the negative effects of low public budget expenditures. Nevertheless, an evaluation of which of the two effects prevails is beyond the scope of this paper, we rather focus on the second channel we mentioned and concentrate on the beneficial effects of public expenditure on the economy.

So far, the literature has mainly focused on public sector's investment in tangibles, such as infrastructures, that can boost productivity in many ways, among which increasing the productivity of private inputs, reducing production and transport costs and encouraging specialization and competition (Bottasso et al., 2013). Less attention has been paid to intangible types of investment, which are also known to be an important source of economic growth.

We aim at bridging these two strands of literature and evaluate different types of intangible investment of the public sector on the productivity of the private sector. To do so, we exploit the industry-level database developed by the EU project SPINTAN (Corrado et al., 2016b) which allows us to disentangle intangibles both by type and by industry of origin. We pair those data with private intangible investment data from INTAN-Invest and with other productive factors data from EU Klems to assess the impact of public intangibles of private productivity. To this end, we use the production function approach, augmenting an otherwise standard production function with both private and public intangible capital components. The final panel dataset includes 19 European countries and 16 industries observed for 13 years, between 2000 and 2012.

The deliverable is structured as follows. Section 2 summarizes the relevant literature, section 3 is dedicated to the description of the data used, section 4 describes the empirical method used, section 5 presents the results and section 6 concludes.

2. Literature review

This study mainly touches two strands of literature: the first is on public capital and the second is on intangible capital. As for the first, contributions to the literature can be distinguished into theoretical and empirical works. From one side, the inclusion of public capital in endogenous growth models dates back to the seminal paper of Barro (1990), which opened a whole new branch of literature on long run equilibrium models, among which we mention Futagami et al. (1993), Glomm and Ravikumar (1997), Fisher and Turnovsky (1998) and Agénor (2010). However, our paper relates more to the empirical part of literature, of which the first milestone is the already mentioned paper of Aschauer (1989) on the impact of public infrastructures on economic growth. In the following years, his results were partially confirmed by several authors, among which we mention Munnell (1990), while criticisms due to the non-stationarity of the variables were raised by others, such as Tatom (1991), Sturm and de Haan (1995) and more recently by Romp and de Haan (2007). The debate has much focused on the estimate of the elasticity output with respect to public capital. In fact, Aschauer (1989) found estimates for the elasticity rather high (~ 0.40), compared to those (below 0.10) estimated by the majority of scholars later (Allen and Arkolakis, 2014; Caselli, 2005; Cubas, 2020; Gramlich, 1994; Holtz-Eakin, 1994; Kamps, 2006). A different approach was followed by others, starting from Morrison and Schwartz (1992), who estimated cost functions rather than production functions. The results of this branch of literature generally confirm a positive effect of public capital in reducing production costs (Heintz, 2010). Also these works confirm the idea that public investment produces a beneficial effect on productivity, but with smaller magnitude with respect to the elasticities estimated by Aschauer (1989) and other early works.

From the other side, the role of intangibles as drivers of growth is commonly recognized in the literature, especially in recent times with global economies being more and more knowledge based. Intangibles are considered one of the possible explanations of the so-called productivity puzzle, the recent slowdown of productivity experienced by many economies. In fact, correcting GDP for unmeasured intangibles makes growth higher, explaining at least partially the puzzle. However, the ambiguous nature of intangibles complicates their measurement and assessment (Nonnis et al., 2021) and only some of them have recently started to be included in national accounts. Moreover, the literature has focus almost exclusively on private intangibles, with very little attention to government spending on this type of assets. The most famous attempt to classify private intangibles is the one made by Corrado et al. (2005), that, evaluating intangibles contribution to growth in the nineties, classifies them in three broad categories: computerized information, innovative properties and economic competencies. The classification was later used in the development of the INTAN-Invest database (Corrado et al., 2016a), which we use in this work and which is the private counterpart of the public intangible database we also employ here. The evaluation of intangible importance for growth and innovation has also intensively been made with case studies and qualitative works. Among them, we mention Chen et al. (2017) and Dedrick (2010), who use a residual approach for evaluating intangible contribution to value added for several case studies (smartphones, coffee, photovoltaic). A similar approach was followed by Gu and Lev (2011), who subtracted normal physical and financial assets returns from firms' earnings to get estimates of intangible assets' returns. From the side of intangible effects on productivity, there are many pieces of work that prove their role as drivers of productivity (Bounfour and Miyagawa, 2014; Oliner et al., 2007; O'Mahony and Vecchi, 2009; Roth, 2020).

As mentioned, the role of public intangibles has been instead explored far less. This is both because the interest in intangibles is a relatively recent thing and because of lack of data availability. Some authors, such as Alencar et al. (2013), Jarboe (2013) and Fernandes et al. (2015), have tried to shed light on this type of investment by the public sector. Some, such as Van Ark and Jaeger (2010) for Netherlands, have tried an evaluation of public sector investment in intangibles at national level, but the first comprehensive attempt to build a global multi-country database is the SPINTAN project, which we use in this study.

3. Data

Our analysis is based on a panel of 19 European countries (Austria, Belgium, Czech Republic, Germany, Greece, Finland, France, Hungary, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden, Slovakia, Slovenia, Spain and United Kingdom) and 16 industries observed for 13 years, between 2000 and 2012, following the ISIC Rev. 4 classification of industries. Public intangible data are taken from the SPINTAN (Smart Public Intangibles) database, and consist of data on intangible investment of five public sector industries, as shown in Table 1. The database is the result of an European project, funded under the FP7 program. In the NACE classification, each industry includes both private and public organizations, or, to use the same terminology in Corrado et al. (2017), market and non-market organizations, where market organizations are those that charge economically significant prices while non-market organizations do not. However, in each industry there can be either only market or non-market organizations or both. Only the five sectors in Table 1 include non-market organizations, while all the other industries are fully private industries. In Figure 1, we report the pattern of total public intangible investment in the five above mentioned sectors in all the countries in the sample over the period considered.

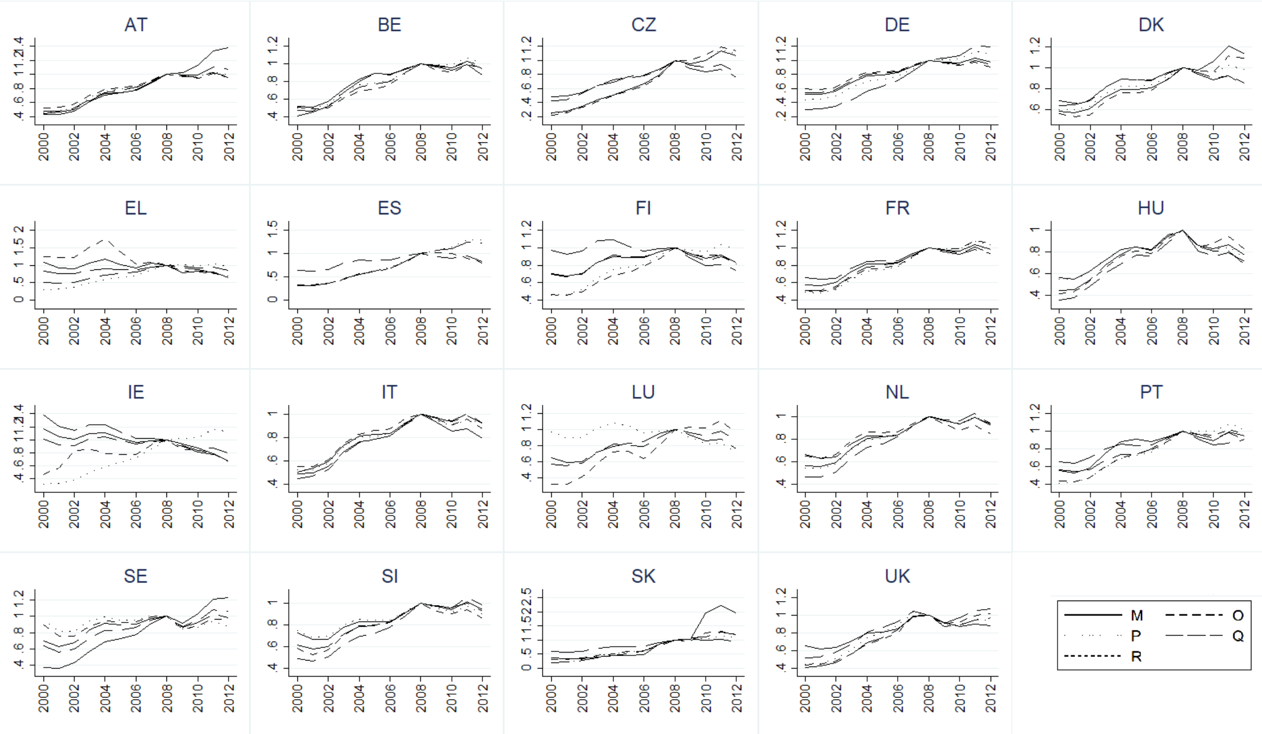
Our data sources also include INTAN-Invest (Corrado et al., 2016a) for private intangible investment. This is the counterparty of the SPINTAN database, providing data on intangible investment for all market industries in the NACE classification. Moreover, the database provides a measure of industrial value added corrected for intangible investment that is not usually included in national accounts.

Table 1: SPINTAN industries

Industry code	**Industry title**	**Nace number**
M	Scientific research and development	72
O	Public administration and defense, compulsory social security	84
P	Education	85
Q	Human health activities (QA) and Residential care; social work activities (QB)	86-87-88
R	Creative, arts and entertainment activities; libraries, archives, museums and other cultural activities; gambling and betting activities; sports activities and amusement and recreation activities	90-91-92-93

Source: Corrado et al. (2016b)

Figure 1. Public intangible investment over time



Note: data have been standardized to 1 for year 2008. Sector letters are according to Table 1. Data source: SPINTAN.

Both SPINTAN and INTAN-Invest distinguish between different types of intangibles. Even though the idea is to keep the intangible categories similar and comparable, there are important differences due to the nature of the sector of origin. These differences are summarized in Table 2. In this study, we keep private intangibles classification as simple as possible, as they are not the main scope of the analysis, while we look more in detail at public intangibles. Therefore, we use the classification firstly proposed by Corrado et al. (2005), reported also in Table 2, which divided private intangibles in software and databases, innovative properties and economic competencies. Of course, some choices are necessary also for public intangibles, as we have two dimensions (intangible type and sector of origin) over which we can classify them, resulting in too many variables in the final econometric model. Hence, we concentrate on three main categories: R&D, software and databases and organizational capital, which represent the three main categories of intangible investment of the public sector in our data.

Table 2: Intangible classification in INTAN-Invest and SPINTAN

Market sector (INTAN-Invest)	**Non-market sector (SPINTAN)**

Computerized Information	Information, scientific and cultural assets
Software	Software
Databases	Open data
Innovative property	
R&D	R&D, basic and applied science
Entertainment	Cultural and heritage, including
Design	arch.& eng. design
Mineral Exploration	Mineral exploration
Economic competencies	Societal competencies
Brands	Brands
Organizational capital	Organizational capital
Firm-specific human capital (training)	Function-specific human capital (training)

Source: Corrado et al. (2016b)

Finally, we complete our database with data on productive factors (tangible capital and labor) from Eu Klems. We use hours worked as proxy for labor, and non-ICT capital stock as proxy for tangible capital. The latter is the result of the aggregation of the following categories: transport equipment, other machinery and equipment, total non-residential investment, residential structures, cultivated assets, research and development, and Other IPP assets. We do not distinguish between public and private tangible capital, as it is not the scope of our study. A summary of the data sources used is provided in Table 3.

Table 3: Data sources

	Database	**Variables**
Public Intangibles	SPINTAN	Public sector investment in intangible capital
Private Intangibles	INTAN-Invest	Investment (at 2010 prices) in R&D, computers and software, design and economic competencies (including organizational capital, branding and training); value added corrected for intangibles.
Productive factors	EU Klems	Labor (hours worked by industry) and non-ICT capital stock (real fixed capital stock at 2010 prices)

4. The empirical model

In order to conduct our empirical analysis, we estimate a production function augmented with intangible component. We do so in two alternative ways. First, we estimate the production function with standard panel methods using value added as dependent variable and controlling for capital and labor as explanatory variables. Alternatively, we estimate a total factor productivity (TFP) proxy in a first step, as residual term from a production function with capital and labor only as explanatory variables, and regress the retrieved proxy on intangible components in a second step. This second method has the important advantage of allowing us to account for capital endogeneity in the first step, using the method developed by Olley and Pakes (1992), that controls for productivity shocks using capital investment as proxy variable for those shocks. In formulas, we can express the standard production function as:

$$Y_{c,i,t} = A_{c,i,t} K_{c,i,t}^{\alpha} L_{c,i,t}^{\beta}$$

Where *Y* is value added, *K* is capital and *L* labor, *A* is a parameter that can be interpreted as total factor productivity, while the indices *c*, *i* and *t* denote respectively country, industry and time. Taking natural logarithms, we get:

$$\log Y_{c,i,t} = logA_{c,i,t} + \alpha logK_{c,i,t} + \beta logL_{c,i,t}$$

Estimating the equation with panel methods, the residual term $logA_{c,i,t}$ is correlated with the inputs. Following Olley and Pakes (1992), and using capital investment as proxy variables, we are able to discern productivity shocks and obtain the desired TFP measure. In the second step, we regress our measure on intangible components to assess their effect on productivity. In formulas, the TFP model will be:

$$TFP_{c,i,t} = \alpha + \beta_1 PrivIntan_{c,i,t} + \beta_2 PublicIntan_{c,i,t} + \varepsilon_{c,i,t}$$

While the value added model is:

$$VA_{c,i,t} = \alpha + \beta_1 K_{c,i,t} + \beta_2 L_{c,i,t} + \beta_3 PrivIntan_{c,i,t} + \beta_4 PublicIntan_{c,i,t} + \varepsilon_{c,i,t}$$

Where *VA* is value added, *TFP* is our total factor productivity proxy, while *PrivIntan* and *PubicIntan* are vectors of private and public intangible component. All variables are considered in logarithms.

As mentioned in the data section, private intangibles include three types of assets: software and databases, innovative properties and economic competencies. As for public intangibles, the three categories we selected are R&D, software and databases and organizational capital. Each of them is included in the model in combination with a sector of origin (e.g. R&D in the education sector, R&D in the health sector and so on). Since public intangible investment involves only five of the industries in our panel, we use the spillover approach to consider their impact on the whole economy. In other words, we assume that each public sector's investment in intangibles spillovers to the whole economy and has a beneficial effect in all the other sectors.

5. Results

5.1 Main analysis

Before showing each combination sector-type of asset, we report in Table 4 the estimates of the models with public intangibles as a whole, that is without distinguishing neither the sector of origin nor the type of asset. Throughout the section, all models are estimated with fixed effects, while robust standard errors are used to prevent heteroskedasticity.

Table 4. Regressions with total public intangibles

Dependent variable	Value added	Value added	Value added	TFP	TFP
	(1)	(2)	(3)	(4)	(5)
Capital	0.932***	0.102	0.140*		
	(0.159)	(0.0742)	(0.0825)		
Labor	0.312***	0.0789	0.157***		
	(0.118)	(0.0571)	(0.0576)		
Econ.comp.		0.525***	0.287***	0.475***	0.206***
		(0.0323)	(0.0370)	(0.0342)	(0.0406)

Innov.prop.		0.0617***	0.0228	0.0525**	0.00859
		(0.0201)	(0.0170)	(0.0226)	(0.0188)
Software		0.0815***	0.0507***	0.0869***	0.0499***
		(0.0139)	(0.0138)	(0.0150)	(0.0146)
total public intangibles			0.0849***		0.102***
			(0.00835)		(0.0102)
Constant	-4.584***	3.460***	0.616	-4.755***	-6.641***
	(1.581)	(0.839)	(0.952)	(0.160)	(0.233)
Observations	3037	2911	2677	2911	2677

Robust standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Specification (1) is the normal production function with only labor and capital as factors. As expected, both of them are significant, even if the significance is reduced when we add intangibles, a phenomenon that can be explained with the correlations among the inputs. In specification (2), we add the three private intangible categories (software and databases, innovative properties and economic competencies), while specification (3) includes public intangibles. The last two specifications are the same as (2) and (3) but using TFP as dependent variable, and therefore not including other productive factors. In all specifications, all the intangible categories - private and public - included are positive and significant.

Let us turn the attention to the sectors of origin. In Table 5 we include in each specification total intangibles from a single sector of origin: scientific research and development (specification 1), public administration and defense (sp. 2), education (sp. 3), health (sp. 4), arts and entertainment (sp. 5). The first three rows include again the three private intangibles categories considered previously. Table 6 reports the same results using value added as dependent variable instead of TFP. Results are confirmed.

Table 5. Regressions by sector of origin

Dep. Var: TFP	(1)	(2)	(3)	(4)	(5)
Econ.comp.	0.358***	0.229***	0.259***	0.416***	0.317***
	(0.0401)	(0.0389)	(0.0315)	(0.0346)	(0.0399)
Innov.prop.	0.0384*	0.0181	0.00687	0.0339	0.0230
	(0.0225)	(0.0191)	(0.0158)	(0.0219)	(0.0195)

Software	0.0808*** (0.0167)	0.0450*** (0.0132)	0.0425*** (0.0120)	0.0764*** (0.0148)	0.0658*** (0.0143)
M-Scientific research and development	0.206*** (0.0399)				
O-Public administration and defense		0.449*** (0.0504)			
P-Education			0.360*** (0.0292)		
Q-Health				0.171*** (0.0318)	
R-Arts, Entertainment					0.272*** (0.0424)
Constant	-5.357*** (0.194)	-6.923*** (0.290)	-6.236*** (0.191)	-5.519*** (0.196)	-5.115*** (0.151)
Observations	2677	2911	2911	2911	2911

Robust standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Table 6. Regressions by sector of origin (using value added as dep. var.)

Dep. Var: value added	(1)	(2)	(3)	(4)	(5)
Capital	0.150* (0.0839)	0.136* (0.0765)	0.00522 (0.0624)	0.124 (0.0828)	0.105 (0.0778)
Labor	0.0790 (0.0569)	0.183*** (0.0536)	0.261*** (0.0593)	0.0934 (0.0567)	0.120** (0.0563)
Econ.comp.	0.417*** (0.0354)	0.308*** (0.0343)	0.345*** (0.0312)	0.469*** (0.0333)	0.384*** (0.0376)
Innov.prop.	0.0482** (0.0197)	0.0310* (0.0174)	0.0232 (0.0146)	0.0446** (0.0194)	0.0354** (0.0175)
Software	0.0753*** (0.0154)	0.0471*** (0.0124)	0.0470*** (0.0115)	0.0719*** (0.0137)	0.0634*** (0.0134)
M-Scientific research and development	0.172*** (0.0312)				
O-Public administration and defense		0.373*** (0.0397)			
P-Education			0.305*** (0.0267)		
Q-Health				0.152*** (0.0290)	
R-Arts, Entertainment					0.238*** (0.0360)
Constant	2.516*** (0.945)	0.102 (0.848)	1.007 (0.847)	2.400*** (0.892)	2.632*** (0.838)
Observations	2677	2911	2911	2911	2911

Standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

Let us turn to the single intangible components. As mentioned previously, we focus on three intangible types: R&D, software and organizational capital. The choice is motivated by the high correlations between all intangible types, that forces us to restrict the number of components to consider, in order to avoid multicollinearity. Results are shown in Table 7. Each column represents a specification for a single sector (from the left to the right: M, O, P, Q, R). In each specification we include public R&D, software and organizational capital investment in that sector, denoted with the abbreviation RD, Sw and OC respectively, right after the sector letter. As the interpretation of the Table may be a little tricky, we underline that the public sector in each column is the sector of origin and not the sector of destination, that is we measure the effect of intangible investment from that sector to the whole economy and not the effect of intangible investment in that sector.

Table 7. Regressions with intangible components

Dep. Var: TFP	(1)	(2)	(3)	(4)	(5)
Econ.comp.	0.237***	0.115***	0.152***	0.202***	0.235***
	(0.0428)	(0.0385)	(0.0384)	(0.0438)	(0.0549)
Innov.prop.	0.0308	0.00728	0.0137	0.0116	0.0821***
	(0.0250)	(0.0173)	(0.0178)	(0.0205)	(0.0267)
Software and db	0.0702***	0.0306**	0.0377***	0.0480***	0.0814***
	(0.0228)	(0.0122)	(0.0128)	(0.0157)	(0.0226)
M-OC-Scientific research and development	-0.00698				
	(0.0427)				
M_RD_Scientific research and development	0.328***				
	(0.0554)				
M-Sw-Scientific research and development	0.0311				
	(0.0245)				
O-OC-Public administration and defense		0.386***			
		(0.0521)			
O_RD_Public administration and defense		0.121***			
		(0.0424)			
O-Sw-Public administration and defense		0.0608**			
		(0.0258)			

P-OC-Education			0.236*** (0.0540)		
P_RD_Education			0.168*** (0.0380)		
P-Sw-Education			0.0807*** (0.0192)		
Q-OC-Health				0.341*** (0.0566)	
Q_RD_Health				-0.00825 (0.0348)	
Q-Sw-Health				0.133*** (0.0321)	
R-OC-Arts, Entertainment					0.288*** (0.0600)
R_RD_Arts, Entertainment					-0.0288 (0.0264)
R-Sw-Arts, Entertainment					0.0655*** (0.0223)
Constant	-5.535*** (0.273)	-6.259*** (0.189)	-5.741*** (0.175)	-5.332*** (0.203)	-5.074*** (0.224)
Observations	1988	2755	2715	2443	1891

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

We summarize the results as follows: 1) the effect of private innovative properties is weaker, being significant only in the last specification (the one for sector R – arts and entertainment); 2) in sector M – scientific research and development, R&D is significant, while software and organizational capital are not; 3) in sector O -public administration and defense and P - education, all three categories are positive and significant; 4) in sector Q – health and R – arts and entertainment, R&D is not significant, while the other two components are. These results seem understandable: R&D from education, scientific research and public administration sector is more effective than R&D from other public industries.

5.2 Public and private intangibles interactions

In this subsection, we explore more in detail the complementarity between private and public intangibles, by means of interaction terms. To do so, we restrict the analysis to three types of intangibles: R&D, software and organization capital, all considered both in their private and public versions. In Table 8 we present the coefficients of each interaction term we tested in separate regressions. We do not report the whole output of each regression for simplicity. Each column represents a sector, so that each cell is the interaction between one private intangible type and one public intangible type produced in a specific sector indicated in the column header. As predictable, the most significant interactions are among intangibles of the same type (private R&D and public R&D for example). Strong complementarities are also found for private R&D with both public software and public organizational capital. Instead, private software and organizational capital are found to haves mixed complementarities with the other public intangibles.

Table 8. Interaction terms

	(M)	(O)	(P)	(Q)	(R)
Private R&D x Public R&D	0.00554***	0.00585**	0.0122**	-0.0327	0.00231
	(0.00175)	(0.00270)	(0.00489)	(0.0380)	(0.00309)
Private R&D x Public Software&Db	0.0133***	0.0110***	0.0123***	-0.00631*	0.0133***
	(0.00320)	(0.00359)	(0.00342)	(0.00371)	(0.00385)
Private R&D x Public Org. Capital	0.0115***	0.00644*	0.0163***	-0.00350	0.00881*
	(0.00339)	(0.00383)	(0.00458)	(0.00452)	(0.00504)
Private Software&Db x Public Software&Db	0.0255***	0.00908**	0.0110*	-0.00347	0.0176***
	(0.00655)	(0.00414)	(0.00631)	(0.00496)	(0.00633)
Private Software&Db x Public R&D	0.0181***	0.00227	0.0171**	-0.0150***	0.00187
	(0.00567)	(0.00532)	(0.00749)	(0.00525)	(0.00635)
Private Software&Db x Public Org. Capital	0.0237***	0.00193	0.0157*	-0.0180***	0.0103
	(0.00679)	(0.00628)	(0.00879)	(0.00504)	(0.00870)
Private Org. Capital x Public Org. Capital	0.0219***	-0.0129*	0.0140	-0.0186**	0.00668
	(0.00826)	(0.00771)	(0.00987)	(0.00790)	(0.0112)
Private Org. Capital x Public R&D	0.0265***	-0.00790	0.0209**	-0.0331***	-0.00634
	(0.00870)	(0.00662)	(0.00904)	(0.0101)	(0.00724)
Private Org. Capital x Public Software&Db	0.0263***	0.00439	0.0114	-0.0306***	0.0175**
	(0.00722)	(0.00557)	(0.00746)	(0.00719)	(0.00813)

Standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01

6. Conclusion

In this study, we analyzed the role of public intangibles as drivers of productivity. Exploiting a recent country-industry database which provides data on investment in intangibles from the public sector, we conducted our analysis via panel regressions. The database allowed us to distinguish intangibles over two dimensions: the sector of origin and the type of intangible. As for the first, we are able to distinguish 5 sectors: M - Scientific research and development; O - Public administration and defense; P – Education; Q - Health and R - Arts and Entertainment. Our approach is to consider the spillover effect of those assets into the whole economy, and not only the effect in their sector of origin. As for the type of intangibles, we focus our attention on three categories: R&D, software and databases and organizational capital.

Among the results, we found evidence in favor of positive effects of many of the public intangible spillovers we considered. Regarding the categories, we found that R&D is more effective when its origin is from knowledge-based sectors such as education and scientific research and development while in sectors such as health and arts and entertainment, organizational capital and software investment produce a stronger spillover effect. Finally, we tested complementarities between private and public intangibles, finding that they are stronger when the origin of the latter is the scientific research and development sector and when they involve the same type of intangible (e.g private R&D and public R&D).

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