Organizational capital, ICT and productivity in the digital age[1]

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Abstract

Research on whether and how intangible assets affect aggregate economic performance has flourished over the past decade, as the measurement of intangibles across industries and countries continuously improved (Corrado et al., 2009, 2012; van Ark et al., 2009; Stehrer et al., 2019). Intangible investments were found to support aggregate labour productivity growth directly as a production input, via interactions with new technologies and by generating important aggregate spillovers. This study looks at synergies between a specific subset of intangibles, "organizational capital" (Prescott and Visscher, 1980; Corrado et al., 2005), and ICT vis à vis aggregate labour productivity outcomes, focusing on the distinction between "own-account" and purchased organizational expenses also looking at high digital intensive industries.

To date, empirical research on the productivity effects of organizational capital has been thin, especially at the macro level. Also, synergies with technology have been studied using broader intangible aggregates, partly due to measurement difficulties (Black and Lynch, 2005), making it hard to identify channels of influence on aggregate productivity. Moreover, while synergies between intangibles and ICT have been repeatedly highlighted (Brynjolfsson and Hitt, 2000; Van Reenen et al., 2010; Marrocu et al., 2012; Chen et al., 2016), there is virtually no macro level evidence on the interplay between organizational capital and digital adoption (Brynjolfsson et al., 2017). Finally, lack of data has also made it impossible to investigate the potentially different roles played by "own account" vs purchased components of organizational capital. Yet, there are reasons to believe that in-house build up of such capital is likely to have different implications for the ability to absorb and use new technologies in a productivity-enhancing way.

We leverage on a new harmonized and fully-integrated productivity database including all intangible components, with broad international, industry and historical coverage (Bontadini et al., *forthcoming;* Corrado et al., 2022a) to address these gaps. Based on a sample of 11 OECD countries and 39 manufacturing and service industries over the 1995-2019 period, we find robust evidence that the benefits of organizational capital for productivity increase with ICT intensity. Moreover, we find that synergies with ICT are driven mostly by investment in "own account" organizational capital. Our results highlight that better internal organization of production is a key channel through which intangible investments affect productivity and are consistent with complementarities between intangibles, new technologies and digital adoption stressed for instance by Brynjolfsson et al., (2017, 2021) and Corrado et al (2017).

Keywords: Organizational capital, Intangible capital, ICT, Productivity, Knowledge diffusion
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1. Introduction

The rising share of intangible assets in total productive capital has been a defining feature of the global economy over the past two decades, stimulating efforts to improve their measurement and better understand their effects on business performance (Haskel and Westlake, 2018; Corrado et al., 2022a). The concomitant diffusion of ICT first and digital technologies next have raised important issues concerning the extent to which intangibles are complementary to these technologies in production. For instance, ICT output elasticities were shown to be very sensitive to accounting for intangible investments in the estimation of production functions at both the aggregate and firm level (Bryjnolfsson and Hitt, 2000a; Corrado et al., 2017). Further, the somewhat disappointing productivity effects of investment in digital technologies were related to the time and expenses needed to build up the matching with intangible capital, which delay technology diffusion and its corresponding benefits (Bryjnolfsson et al., 2017). Another set of issues concerns the extent of production spillovers originating from the partially non-rival nature of intangibles (Goodridge et al., 2017; Corrado et al. 2017). Interestingly, both failure to capture complementarities between intangibles and new technologies and weak (or declining) spillovers from intangibles have in turn been mentioned as explanations of differential productivity contributions of ICT across countries (Van Reenen et al., 2010; Gal et al., 2019) and possible co-drivers of the global productivity slowdown (Corrado et al., 2022b).

Typically, economic research has focused either on effects of various measures of total intangibles (e.g. Niebel et al., 2017; Roth and Thum, 2013; Corrado et al., 2022a) or on specific components, such as R&D (Griliches, 2007) -- for which data were readily available in both company and National Accounts -- and (more recently) managerial skills, especially since reliable cross-country survey data were collected (Scur et al., 2021). Yet R&D and managerial skills are single components of larger intangible aggregates -- innovative property and economic competencies, respectively, using Corrado et al. (2005) widely accepted taxonomy. These larger aggregates include several other investments that are not only potentially complementary to R&D and managerial skills but also possibly more impactful on firm-level and aggregate performance. Notably, investment in managerial skills can hardly be separated from other investments in organizational changes on both the supply and demand sides of business activity -- such as supplier chains, branding and customer relationships. Indeed, investment in managerial competencies makes these organizational changes possible, but good management requires in turn complementary investment these assets. Hence, looking at the joint effects on productivity of an aggregate measure of organizational changes, i.e. the so-called "organizational capital" (OC) component of intangible assets, rather than just on its managerial component seems appropriate.

Theory and evidence from the business management literature suggest that OC is likely to be highly synergetic with investments in ICT and digital technologies (Bryjnolfsson and Hitt, 2000; Li et al., 2006), as its acquisition is at the same time enabled by the use of these technologies in production and enabling their adoption. Also, its effect on performance may differ depending on whether OC is acquired commercially (e.g. by purchasing intellectual services) or built up within the firm – which durably improves internal capabilities to absorb new technology. At the same time, the extent of spillovers generated by OC is more uncertain than for other intangibles, as much of it is tacit knowledge or is covered by trade secret.

Notwithstanding its potential relevance for economic performance in the context of the digital transformation, empirical research on the actual role played by OC has been limited, especially at the aggregate level, partly due to difficulties in appropriately measuring such assets (Black and Lynch, 2005).[2] Moreover, to our knowledge virtually no evidence is available on the differential productivity effects of own-account versus purchased components of OC.

In this paper, we contribute to fill this gap by leveraging on new aggregate data on intangibles by Corrado et al. (2022a) (described in Bontadini et al.(2022), *forthcoming*), who not only explicitly measure OC at the detailed industry level but also distinguish between "own-account" and purchased components of these assets.[3] The subsample of the data used in this study covers 39 manufacturing and service sectors in 9 EU countries the UK and the US over the 1995-2019 period. We use these data to investigate the aggregate complementarity between investment in ICT and in OC vis à vis labour productivity outcomes as well as to explore whether this complementarity is affected by the nature of OC expenditure and the digital intensity of different industries. Throughout the analysis, we focus on the effects of various types of capital on output per hour controlling for country and industry characteristics as well for economy-wide shocks, using the production model proposed by Corrado et al. (2017).

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[2] The few empirical analyses of the effects of OC on productivity and of its complementarity with ICT and digital technologies were performed at firm level (e.g. Tronconi and Vittucci Marzetti, 2011; Crespi et al., 2007), often in the context of business management research studies (see Ruales Guzman et al., 2019, for a recent survey of some of this literature).

[3] EUKLEMS-INTANProd is a harmonized and fully integrated productivity database including all intangible components, with broad international, industry and historical coverage (see https://euklems-intanprod-llee.luiss.it/). Data distinguishing own account ftrom purchased components of OC that are used in this paper are currently not yet publicly available but can be provided by the authors upon request.

We take advantage of the distinction between own account and purchased components of OC to test the hypothesis that what matters most for performance in a rapidly changing business environment is the build up of in-house organizational knowledge. This is consistent with findings in management studies that relate the ability to reap the full benefits of IT to a set of organizational capabilities internal to the firm (e.g. Teece et al., 1997). These include the ability of managers to elicit information synergies and innovativeness as well as the existence within the firm of "positional assets" (such as technological know-how, reputation and organizational culture) and agile processes (notably with customers and suppliers) (Li et al., 2006).

Our results extend to the aggregate level past firm-level findings concerning the OC-productivity nexus and, especially, bring additional insights on the parallel effects of digitalization and organizational change on aggregate productivity, with brand new evidence on the leading role played by in-house organizational assets. We show that the stock of OC is positively associated with productivity growth and this positive association is increasing with industry ICT intensity, confirming the strong synergies between OC and ICT found in previous firm-level research. In any given industry, the estimated unconditional effects of increasing the stock of OC and ICT on productivity are quantitatively comparable, but these effects are higher when estimates are conditioned on industry ICT intensity. Exploiting the detail in our aggregate data, we show that these results are driven by own-account investment in OC. Both the unconditional and conditional effects of the OC stock on productivity growth in digital-intensive industries are quantitatively determined mostly by its own-account component. This provides empirical support for the intuition that better internal organization of production and sales (including managerial capacity, branding, supplier and customer networks) and better ability to develop and adapt this organization to a rapidly changing business environment are key channels through which intangible investments affect productivity in the context of the digital transformation.

Finally, estimating our production model over industry sub-groups classified by digital intensity as in Calvino et al. (2018), the results suggest that ICT mediates the influence of OC on productivity in highly digitalized industries. This brings fresh evidence on the role played by OC in facilitating the efficient use of digital technologies and generating productivity returns.

Our analysis contributes in several ways to past empirical research investigating the link between OC, new technologies and economic performance. First, our aggregate evidence complements the relatively few studies focusing on the influence of various measures of organizational assets on firm performance. For instance, Tronconi and Vittucci Marzetti (2011) find high output elasticities to OC measured capitalizing SD&A expenses from balance sheets of a sample of European firms. Papanikolaou and Eisfeldt (2009) use similar accounting data to focus instead on the effects of OC on firm stock market returns, showing that firms with more OC significantly outperform other firms.[4] Using our data, we provide hitherto lacking evidence of the aggregate effects of OC on labour productivity at the industry and country levels.

Second, our macro level analysis also complements the relatively thin firm-level evidence concerning the interplay between ICT and OC in affecting business performance. In a study using a large-scale cross-country firm-level database on ICT and productivity, Van Reenen et al. (2010) highlight that the above-normal estimated returns from ICT investment are consistent with the hypothesis that unmeasured assets play an important mediating role. Digging deeper they find complementarity between ICT and a crude survey-based measure of firm organizational assets (decentralization of production). Based on UK firm-level data, Crespi et al. (2007) also find that ICT and a measure of organizational change show synergies vis à vis their effects on productivity. A few other business management studies find evidence that the complementarity with various measures of firm level OC is an important factor affecting the effects of ICT investment on company performance. For instance, focusing on a sample of US firms, Aral and Weill (2007) show that specific IT assets yield expected returns on a range of strategic business objectives, especially when they are associated with capabilities in allocating and organizing IT within the firm. Liu and Ravichandran (2007) find similar results based on a sample of chinese non state-owned firms: returns to IT investment in industries with high informative content are increasing with OC as measured by managerial human capital. Young and Tsai (2011) also find that the effects of IT investments on business performance (measured by Tobin's Q) are mediated by organizational practices based on a sample of Taiwanese firms. All these studies used very partial measures of OC and none of them focused on aggregate effects on productivity of its interplay with ICT. Instead, we use an exhaustive measure of OC investment and study how its effect on aggregate productivity is mediated by ICT intensity.

Finally, we fill an important gap in the empirical literature concerning which component of OC is responsible for the synergies with ICT identified in previous firm-level research. Thanks to

[4] A much more prolific strand of research has looked at the influence of a specific element of OC, managerial capacity, on productivity relying on various measures including those first collected by Bloom et al. (2009, 2012). Scur et al. (2021) and Guzman et al. (2019) survey economic and business management studies in this area, respectively.

the fine level of detail in our new OC data, we are the first to pinpoint the sources of the beneficial effects of OC on productivity, highlighting the prominent role played by own-account investment relative to other ways of increasing organizational capabilities, such as the purchase of services on the market. This extends to the aggregate level insights of managerial studies highlighting the importance of considering successful business outcomes in the digital era as resulting from the ability to exploit the full set of organizational assets of the firm -- including both IT and organizational capabilities – in order to favour flexibility, responsiveness and innovativeness (Tsou and Chen, 2021).

We also look explicitly at the role played by OC in the context of the digital transformation. Previous empirical research on the interplay of OC and digitalization is very limited and mostly based on industry-specific case studies (largely focused on the US), the most well-known being Brynjolfsson and Hitt (2000) and Brynjolfsson et al. (2002). [5] Leveraging on our data, we are the first to provide aggregate evidence for a large number of countries and industries that OC investment is instrumental in raising productivity in industries with a high level of digitalization.

Given the complexities involved in the link between OC and productivity in different industries and countries (e.g. related to differences in the size distribution of firms, the skill distribution of workers), the multiple dimensions taken by investment in OC (e.g. management, logistics, branding, etc.) and the causality issues involved in studying synergies between various kinds of investments affecting productivity, our contribution is just a first step in a broader research agenda. We control for country and industry fixed effects and use a GMM estimator that is robust to potential endogeneity to account for some of such complexities and issues. However, the analysis of the influence of OC on aggregate productivity surely deserves a more detailed treatment in the future and we indicate in the conclusions some directions for future research in this field.

Following this introduction, the next section describes our data and provides some suggestive evidence on the links between OC, ICT, digital intensity and labour productivity at the industry level. Then we illustrate our empirical strategy ansome preliminary findings on the productivity effects of organizational capital focusing on synergies of OC with ICT and digitalization as

[5] See, however, the recent study by Tsou and Chen (2021), which focuses on a sample of Taiwanese firms in the financial industry.

well as on the channels through which these synergies come about. We conclude the paper with a discussion of possible future research directions and the implications for policy.

2. Data and descriptive evidence

We rely on the latest release of the EUKLEMS-INTANProd data, for a subsample of countries[6] over the 1995-2019 period. The dataset updates the widely used EUKLEMS data on production, value added and investment with estimates of intangible assets that are not included in national accounts, following the taxonomy put forward by Corrado et al (2005).

The current System of National Accounts (SNA 2008) only includes a limited number of intangible assets within its asset boundary: (i) R&D, (ii) computer software and databases, (iii) mineral exploration, and (iv) entertainment, literary and artistic originals. As a consequence, the remaining assets identified in Corrado et al (2005) are treated as intermediate expenditure, these include: (i) Design, (ii) Advertising and Market research (Brand), (iii) Training and, crucial to our purpose here, (iv) Organisational capital.

For Organisational capital, as well as Design and Brand, EUKLEMS & INTANProd provides measures of investment and stock as the sum of a purchased and an own-account component. Both components are computed with an expenditure approach. The purchased component relies on information on expenditure data from the Use Tables compiled by Eurostat (and the Bureau of Economic Analysis for the US). The own-account component also relies on a cost approach, consistent with methods used by national statistical offices to estimate investment in Computer software and databases. Additional information on the methodology can be found in Bontadini et al. (*forthcoming*).

By using distinct measures of the accumulated stock of organisation capital for the purchased and own-account component in this paper, we are able to distinguish between two key ways in which companies, and industries at the aggregate level, accumulate organisational capital. The purchased component captures the expenditure for legal, accounting and management services. The own account component captures expenditure on workers with managerial position within the company. While these two kinds of expenditure are related, they involve different kinds of knowledge and capabilities that are likely to interact with the acquisition of new technologies and the digitalisation process in different ways.

[6] The countries included in our analysis are Germany, Denmark, Spain, Finland, France, Italy, the Netherlands, Sweden, the United Kingdom and the United States.

To capture the extent of digitalisation, we rely again on information available in EUKLEMS & INTANProd. We aggregate stocks at constant prices for communication equipment, computing equipment and computer software and databases to obtain a measure of the total stock of ICT assets.

Our main variable of interest is labour productivity, which we measure using value added per hour worked. In order to account for the inclusion of non-national account assets into our analysis, we rely on the adjusted value added provided in EUKLEMS & INTANProd. This is the national account value added augmented with the investment in non-national account assets described above (Corrado et al 2005).

As a first piece of evidence, we turn to the dynamic of our main variable of interest, within the market sector, excluding agriculture. Figure 1 reports the average growth rate of adjusted value added at constant prices per hour worked, a standard indicator of labour productivity, for the periods before and after the 2008 financial crisis in order to have a clearer image of the main trends afoot.

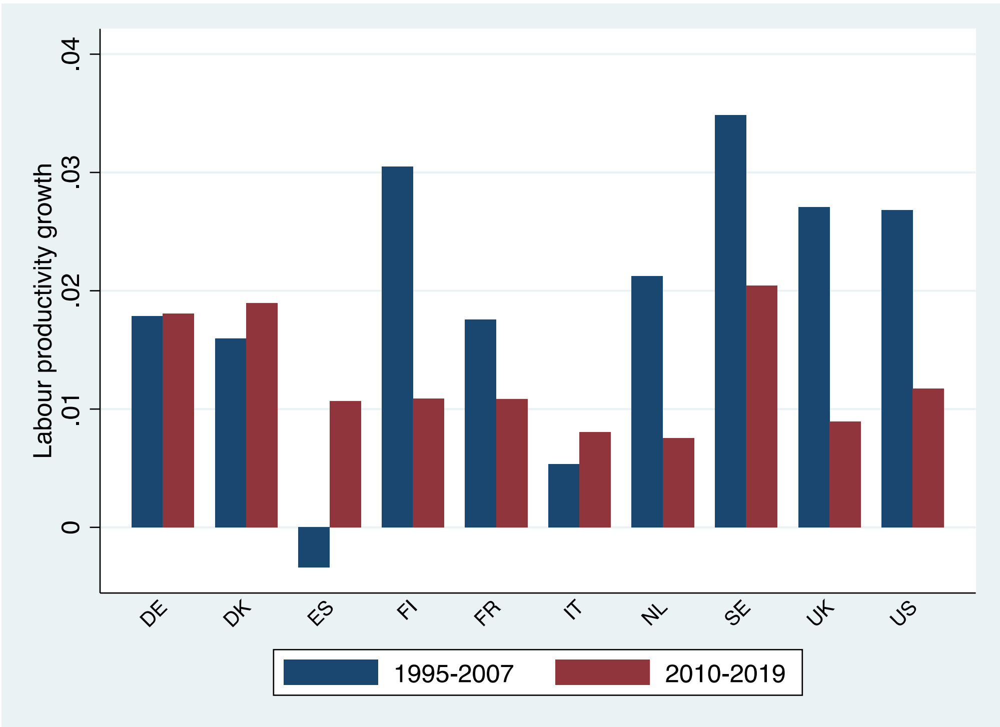


Figure 1 – Average growth rates in adjusted value added at constant price per hour worked, across countries over the 1995-2007 and 2008-2019 periods, in the market sector excluding agriculture.

Source: authors' calculations on EUKLEMS & INTANProd data.

Consistent with the generalized productivity slowdown, countries that have experienced highest growth rates in labour productivity in the pre-crisis period – such as Sweden, the US, the UK and Finland – have seen a decline in the average rate of growth after the financial crisis. Italy has experienced, in both periods the lowest productivity growth among the countries in our sample, although labour productivity has grown at a faster rate in the years following the financial crisis. Spain is the only country to have negative average growth rates in labour productivity before the financial crisis, while this has become positive in the years from 2010 onwards. Germany in contrast seems to have had sustained growth in labour productivity both before and after the financial crisis.

One of the key features of the EUKLEMS & INTANProd data is that it integrates national account assets with non-national accounts intangible assets. Among these, our interest lies with organisational capital and, in particular, its interaction with ICT capital. It is important therefore to explore the dynamics of investment across ICT, intangible assets[7] and organisational capital, as a share of adjusted value added, at current prices. Figure 2 reports country-level averages of our entire period of interest, showing that intangible assets represent a significant share of value added, hovering between 7 and 16 percent across countries. This is significantly larger than the share of ICT investment. However, it is worth noticing that ICT investment is larger in countries with larger investment in intangibles and organisational capital, notably Sweden, Denmark, France and the Netherlands, suggesting that these two groups of assets are likely to move together.

[7] Intangible assets includes both the national accounts (R&D, Software and OIPP) and non-national accounts assets.

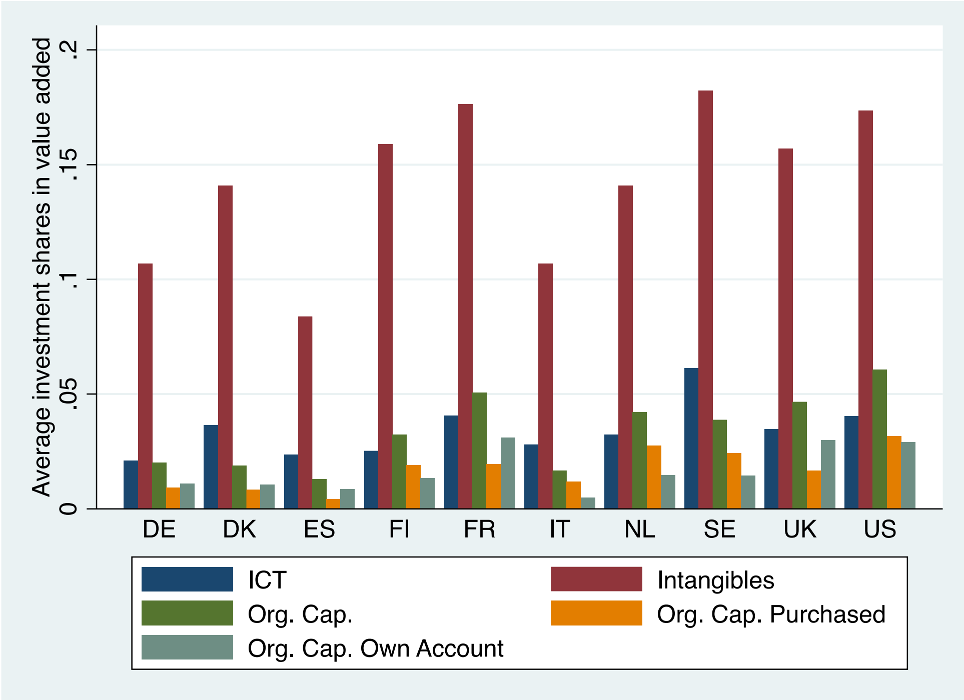


Figure 2 – Investment in ICT and Organisational capital, breaking down purchased and own account, as a share of adjusted value added at current prices in the market sector, excluding agriculture.
Source: authors' calculations on EUKLEMS & INTANProd data.

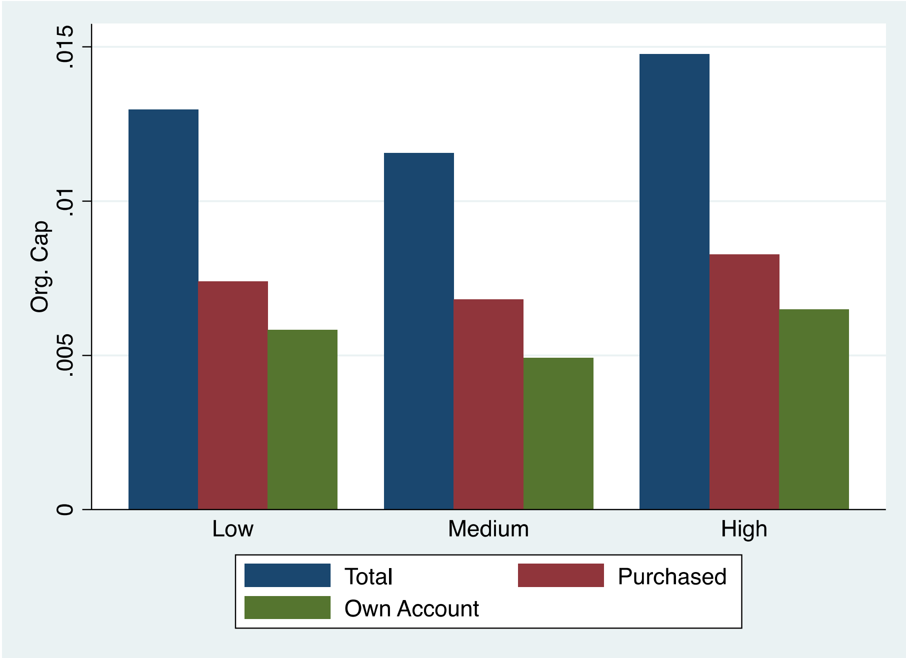
Furthermore, Organisational capital also accounts for a sizeable portion of investment in intangible assets. With respect to the adjusted value-added organisational capital varies between 2 and 5 percent. Figure 2 also shows that both own-account and purchased components account for a significant share of total investment in organisational capital. We can also see differences in the shares of the two components across countries. For example, own account organisational capital is significantly larger than the purchased component in both France and the UK, while the opposite is true in Spain, the Netherland and Sweden. Differences in the composition of organizational capital could partly account for different productivity outcomes across countries, highlighting the importance of distinguishing between these two components when studying their relationship with productivity growth.

We have so far discussed evidence at the aggregate level, looking at the market sector, excluding agriculture. In order to further study the relationship among ICT and organisation capital, we also explore how intensity in organisational capital varies across industries, based on how digitally intensive these are.

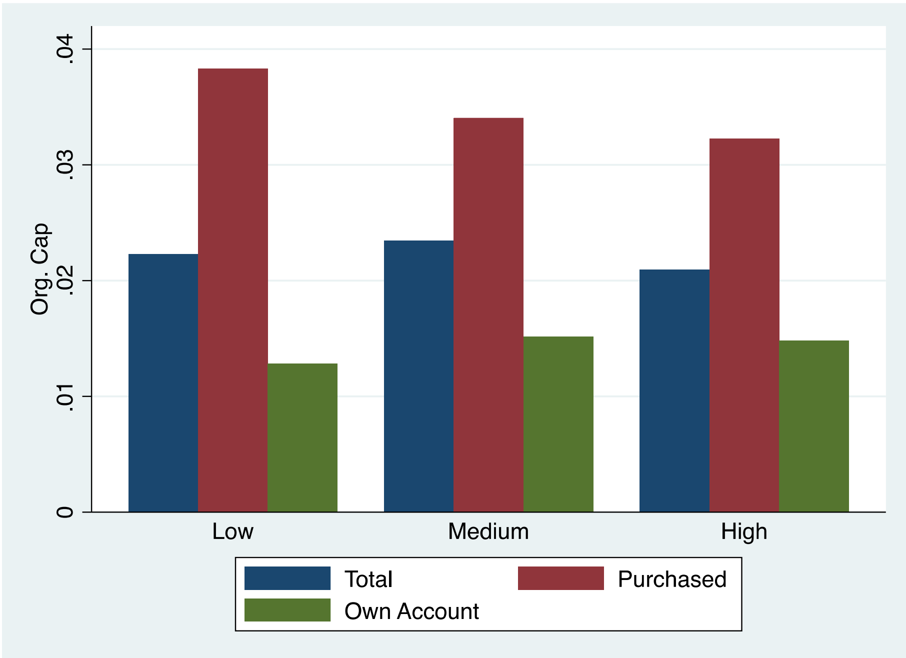
In order to classify industries by their digital intensity, we start from the taxonomy proposed by Calvino et al (2018), who rank industries in quartiles, according multiple criteria. We only use those that are applicable and available for all industries[8]: (i) Software investment, (ii) ICT tangible investment (iii) intermediate purchase of ICT services, and (iv) ICT specialists in the workforce. We then compute for each industry the mean of the quartile to which it belongs across the four criteria and identify these as high digital if the mean is above three, medium if it is two and low otherwise – we report a table detailing this in the Appendix, Table A1.

Once we have allocated each industry to one of the three groups, we look at the average stocks of organisational capital, in per hours term and at constant prices both in levels and growth rates in Figure 3 Panel A and B, respectively. In the first panel, as expected, high digital industries have also the highest intensity in organisational capital both when looking at the total and its two components separately. It is however interesting that low digital industries have, on average, larger organisational capital than medium ones. Panel B provides a rather different picture. Average growth rates of the stock of organisational capital are highest among low digital industries and lowest among high digital ones, for the purchased component, while own account organisational capital grows faster in medium and high digital industries. This again suggests that purchased and own account have rather different dynamics also across industries and that the way they interact with digital intensity could be different. Overall, Figure 3 shows that the stock of organisational capital has grown faster in industries with lower stocks, hinting at a convergence in the diffusion of organisational capital across industries.

[8] Specifically, we use: (i) Software investment, (ii) ICT tangible investment, (iii) intermediate ICT services, and (iv) ICT specialists. We exclude from our analysis (i) intermediate ICT goods, which is not applicable to the manufacturing industries that produce these goods, (ii) robot use which is not available for services and online services which is not available for finance, mining and, arts and entertainment.



(*A*)



(*B*)

Figure 3 – Levels and growth rates in organisational capital and its components across industries by digital intensity, averaged over countries and years.
Source: authors' calculations on EUKLEMS & INTANProd data.

Finally, before turning to our econometric analysis, we provide some *prima facie* evidence of the main relationship of interest. Figure 4 shows labour productivity growth plotted against organizational capital stock, in per hours terms, as an aggregate and versus its components.

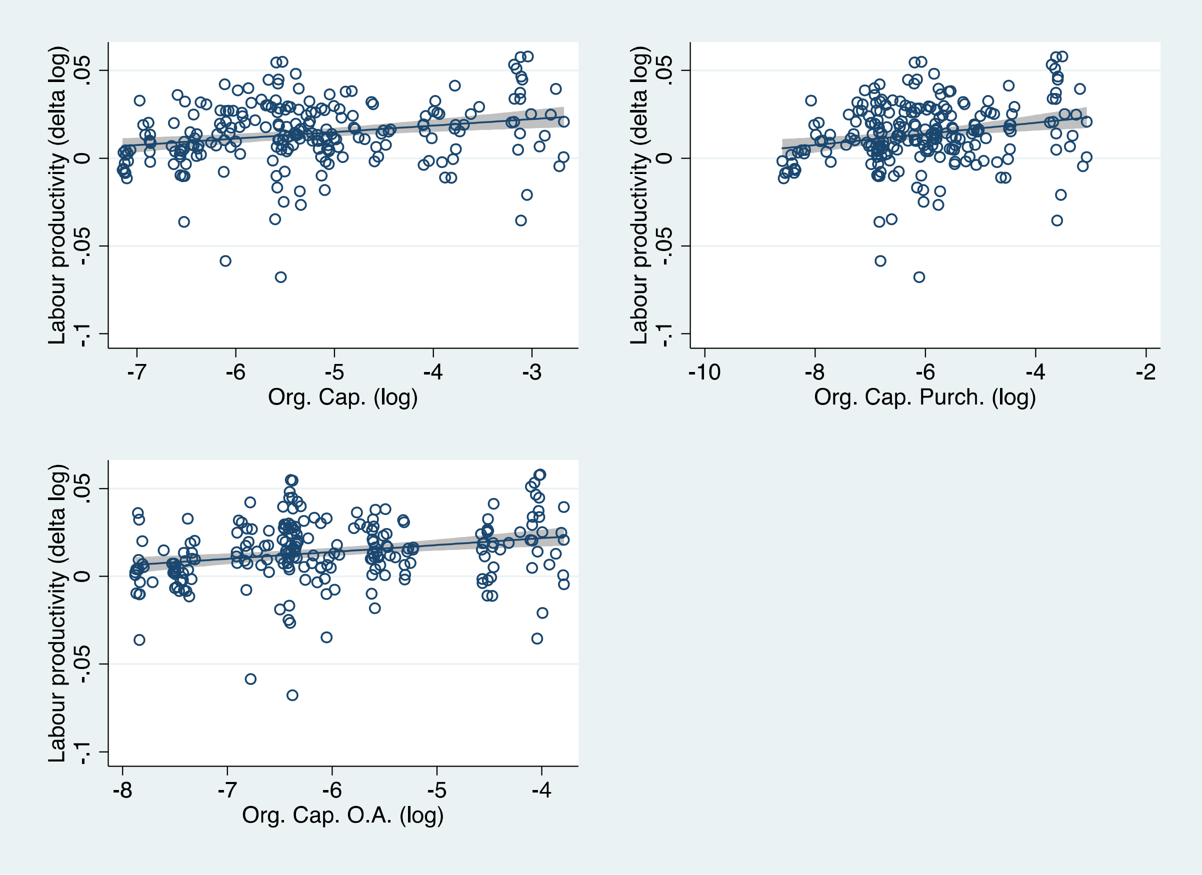


Figure 4 – Labour productivity growth and the stock of organisational capital, in per hours term: total, purchased and own account in log, for the market sector excluding agriculture. *Source:* authors' calculations on EUKLEMS & INTANProd data.

We find a positive and statistically significant relationship across all three panels, indicating that at the aggregate level economies that are more intensive in organisational capital also experience faster growth in labour productivity. This appears to hold regardless of which component of organisational capital we look at, at least in terms of descriptive evidence. In order to ascertain the robustness of this relationship we estimate a production model that includes changes in capital per hour worked (across different asset groups), controlling for time trends and possible reverse causality. We discuss these issues in detail in the following section.

3. Empirical strategy and main findings

Corrado et al (2017) showed that ICT and intangibles are complements in a production process where ICT productivity returns are enhanced by interactions with intangible assets. They tested the complementary effect resorting to an augmented production function model with interactions à la Rajan and Zingales (1998). In this paper, we adopt a more general approach to investigate if country-industries endowed with relatively larger stock of organizational capabilities experience faster productivity growth in more ICT intensive sectors. We also check if the synergies between ICT and organizational capital vary across the purchased and own account components of organizational capital, and if the complementary effect differs in high digital intensive industries.

Thus, our benchmark specification is as follows:

$$(1) \qquad \Delta \ln(Y/H)_{i,c,t} = \alpha_1 \Delta \ln(K^{I}/H)_{i,c,t} + \alpha_2 \Delta \ln(K^{T}/H)_{i,c,t} + \alpha_3 \ln(K^{OC}{}_{j}/H)_{i,c,t-1} + \alpha_4 \ln(\overline{K^{ICT}}/H)_{i,avg} + \alpha_5 \ln(K^{OC}{}_{j}/H)_{i,c,t-1} * \ln(K^{ICT}/H)_{i,avg} + \lambda_c + \lambda_t + \tau_i + \eta_{i,c,t} .$$

where variables vary by country c, industry i and time t; Y denotes value added adjusted to include intangible capital (as in Corrado, Hulten, and Sichel 2005, 2009), H is total hours worked, K^{I} is intangible capital, K^{T} is Tangible capital, while $(K^{OC}{}_{j}/H)$ refers to Organizational capital intensity with j=total, purchased and own account, and $(K^{ICT}/H)_{i,avg}$ denotes country-time average (log) intensity of ICT capital per hours, λ_c , λ_t are country and time dummies and τ_i is an industry trend. Notice that a characteristic of multiplicative interaction models is that they are symmetric with respct to the interacted terms. Thus the interaction variable in equation (1) does not imply anything for the casual relationship between the intensities of organizational capital and ICT (Brambor, Clark and Golder, 2006). We assume that ICT is our conditional variable affecting the impact of organizational competences on productivity growth. In other words, we assume that the outpur elasticity of organizational capital stock depends on ICT intensity. If our assumption is correct, we should find that in equation (1) $\alpha 5 > 0$, indicating that each country industry experiences relatively higher productivity growth when organizational capabilities complement ICT capital intensity.

Ultimately, the estimation of equation (1) can be affected by structural identification problems related to measurement error, multicollinearity, and endogeneity of factor inputs. Thus, we also test our results with IV and GMM estimation (Ackerberg et al 2015).

3.1 Empirical results

Table 1 shows the estimation results of our benchmark specification, equation (1). All regression models contain country and time fixed effects and are estimated both by GLS and GMM. Columns 1 to 6 refer to the market sector excluding agriculture while columns 7 to 12 test equation (1) only in the high digital intensive sectors (Calvino et al., 2018).

Column 1 tests the complementary effect of ICT and organizational capital on productivity growth and shows positive and statistically significative coefficients for the interacted terms[9]. This result is confirmed also by GMM estimates (Columns 4). Thus our findings support the assumption of larger productivity returns from the synergy between higher organizational capabilities and ICT. Columns 2-3 and 5-6 test the benchmark specification distinguishing between purchased and own account organizational capital and their respective interactions with ICT intensity. Synergies between purchased managerial consultancies and ICT are estimated to be weaker than those with own account organizational capital even when controlling for possible endogeneity biases (columns 5 and 6).

To further explore factors possible affecting the complementarity between ICT and managerial capabilities, we also test the benchmark specification in high digital intensive sectors as defined by Calvino et al (2019). Both GLS and GMM estimates weakly support the assumption of a complementarity in highly digital intensive sectors. The complementarity is estimated to have an equal impact across investments in own account and purchased organizational capabilities, suggesting that, in highly digitalized industries, organizational capabilities that are important for the productive use of ICT can be effectively improved both by enhancing internal managerial know-how and by relying on external resources. The marginal effect of the stock of organizational capabilities on productivity growth between the 5^{th} and 95^{th} percentile of the distribution of $\ln(K^{ICT}/H)_{i,avg}$ is increasing as the degree of ICT intensity increases. To get some ideas of the numbers involved, the elasticity of $\ln(K^{OC}{}_{j}/H)$ at the 5^{th} percentile of the $\ln(K^{ICT}/H)_{i,avg}$ distribution is 0.005 whereas at the 95^{th} percentile is 0.15. The marginal effect of organizational capabilities becomes stronger for own account organizational capital showing an elasticity of 0.008 at the 5^{th} percentile of the distribution of ICT intensity and 0.019 at the 95^{th} percentile,

[9] Notice that for each estimated regression the interacted terms are included as controls but not reported in the table for the sake of simplicity. Extended tables for regression results are available from the authors under request.

To summarize, all interaction effects are positive but with varying statistical significance between purchased and own account organizational capital. This support the assumption that better organizational capabilities, especially those developed in house as captured by own account organizational capital, are a key factor for generating larger productivity returns from advanced technology, especially for digital intensive activities.

Table 1 – Benchmark estimates – Testing the complementary effect of ICT and Organizational capital on productivity growth

	GLS			GMM			GLS			GMM		
							High digital			High digital		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
VARIABLES	Total	Purchased	Own Acc.	Total	Purchased	Own Acc.	Total	Purchased	Own Acc.	Total	Purchased	Own Acc.
$\Delta\ln(K^{I}/H)_{i,c,t}$	0.193***	0.194***	0.185***	0.507***	0.472***	0.277*	0.241***	0.237***	0.238***	0.358***	0.417***	0.395***
	(0.0182)	(0.0182)	(0.0181)	(0.163)	(0.166)	(0.162)	(0.0231)	(0.0232)	(0.0234)	(0.0840)	(0.0882)	(0.0864)
$\Delta\ln(K^{T}/H)_{i,c,t}$	0.187***	0.183***	0.187***	0.432*	0.510**	0.413*	0.163***	0.163***	0.168***	0.296***	0.307***	0.315***
	(0.0217)	(0.0217)	(0.0214)	(0.232)	(0.228)	(0.231)	(0.0269)	(0.0269)	(0.0269)	(0.100)	(0.0995)	(0.0950)
$\ln(K^{OC})_{i,c,t-1}$	**0.0168*****			**0.0422*****			0.00610			0.00904		
	(0.00594)			**(0.0135)**			(0.00737)			(0.0113)		
$\ln(K^{OCPur})_{i,c,t-1}$		0.00761			**0.0260****			0.00661			0.0143	
		(0.00493)			**(0.0116)**			(0.00612)			(0.00915)	
$\ln(K^{OCOwA})_{i,c,t-1}$			**0.0251*****			**0.0435*****			0.0142**			0.0141
			(0.00495)			**(0.00961)**			(0.00589)			(0.00882)
$\ln(K^{OC})_{i,c,t-1} * \ln(K^{ICT}/H)_{c}^{avg}$	**0.00216****			**0.00670*****			**0.00199***			**0.00285***		
	(0.000850)			**(0.00185)**			**(0.00112)**			**(0.00165)**		
$\ln(K^{OCPur})_{i,c,t-1} * \ln(K^{ICT}/H)_{c}^{avg}$		**0.00137***			**0.00457*****			**0.00177***			**0.00275***	
		(0.000777)			**(0.00169)**			**(0.000987)**			**(0.00148)**	
$\ln(K^{OCOwA})_{i,c,t-1} * \ln(K^{ICT}/H)_{c}^{avg}$			**0.00287*****			**0.00610*****			**0.00168***			**0.00243***
			(0.000713)			**(0.00144)**			**(0.000913)**			**(0.00136)**
Observations	3,608	3,608	3,608	3,160	3,151	3,148	2,053	2,053	2,053	1817	1817	1817
Country Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses

***** p<0.01, ** p<0.05, * p<0.1**

Note:

4. Conclusion and policy suggestions

This paper leverages on new data that combine in a coherent way detailed information on intangible investments with production accounts at the industry level to explore the aggregate effects of organizational capital on productivity, an issue investigated so far only in a handful of firm level studies. We focus on how these effects change depending on industry ICT intensity and level of digitalization as well as on the type of organizational capital built up in the industry, distinguishing between own account and purchased organizational assets. Extending previous firm-level results, we find that organizational capital brings sizeable aggregate productivity gains and that gains are higher in ICT-intensive industries, suggesting industry-wide synergies between these technologies and the accumulation of organizational knowledge. These synergies appear to be mostly related to the accumulation of internal knowledge via own-account investments, though also the purchased component plays a role. The positive synergies between organizational capital and ICT are uniform across industries and do not appear to depend on the level of industry digitalization. In other words, investing in organizational capital brings productivity benefits to high and low digitalized industries alike.

Our results are preliminary and more research is needed to test their robustness, better understand the channels and extend the analysis in several directions. Especially, the interaction between investment in organizational capital and the information content of production in different industries deserves further attention, as one may expect responsiveness, adaptability and flexibility of business models to become particularly influential on productivity when the role of data rises. More specifically, one would expect the relevance of organizational capital for productivity to increase with the level of innovativeness of production, suggesting that its positive effects may be stronger as R&D spending increases. In short, exploring the relationship between organizational capital and other kinds of intangibles would seem a promising avenue of future research.

Policy-wise our results suggest that promoting investments in ICT, e.g. via tax incentives or subsidies as implemented in many countries, can only reap the intended aggregate productivity benefits if these measures are coupled with initiatives aimed at upgrading the organizational capital of firms, especially of those firms that are most disadvantaged vis à vis this kind of investment, such as SMEs. Action in this area is fraught with difficulties -- related for instance to the selection of the targeted firms, the choice of instrument(s) and the criteria for policy evaluation – and international policy experience from which to draw lessons is not abundant. Nonetheless, both studies of historical experiences -- such as the effects of postwar US management training programmes on the productivity of Italian firms (Giorcetti, 2019, and Bianchi and Giorcetti, 2021) -- and of recent incentive and support programmes implemented in India (Bloom et al., 2013), Mexico (Bruhn et al., 2018) and Italy (Manaresi et al., 2022) suggest that, if well-designed, policies that encourage or facilitate the accumulation of organizational know-how within firms can be very effective in improving efficiency and performance.

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Appendix – Table A1

Industry	Industry description	Digitalisation criteria: Software investment	ICT equipment investment	Intermediate ICT services	ICT specialists	Mean
A	Agriculture, forestry and fishing	1	1	1	1	**1**
B	Mining and quarrying	1	1	1	2	**1**
C10-C12	Food products, beverages and tobacco	2	1	1	1	**1**
C13-C15	Textiles, wearing apparel, leather and related products	3	3	2	2	**3**
C16-C18	Wood and paper products; printing and reproduction of recorded media	3	2	3	3	**3**
C19	Coke and refined petroleum products	2	1	1	4	**2**
C20	Chemicals and chemical products	1	2	2	4	**2**
C21	Basic pharmaceutical products and pharmaceutical preparations	1	1	2	4	**2**
C22-C23	Rubber and plastics products, and other non-metallic mineral products	3	2	2	2	**2**
C24-C25	Basic metals and fabricated metal products, except machinery and equipment	2	2	2	1	**2**
C26	Computer, electronic and optical products	3	1	4	4	**3**
C27	Electrical equipment	3	2	3	3	**3**
C28	Machinery and equipment n.e.c.	3	3	3	2	**3**
C29-C30	Transport equipment	3	2	3	4	**3**
C31-C33	Other manufacturing; repair and installation of machinery and equipment	4	2	3	3	**3**
D-E	Eectricity, gas, steam; water supply, sewerage, waste management	1	2	2	3	**2**
F	Construction	2	3	1	1	**2**
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	4	4	3	2	**3**
G46	Wholesale trade, except of motor vehicles and motorcycles	4	4	3	2	**3**
G47	Retail trade, except of motor vehicles and motorcycles	4	4	3	2	**3**
H49	Land transport and transport via pipelines	1	1	2	1	**1**
H50	Water transport	1	1	2	1	**1**
H51	Air transport	1	1	2	1	**1**
H52	Warehousing and support activities for transportation	1	1	2	1	**1**
H53	Postal and courier activities	1	1	2	1	**1**
I	Accommodation and food service activities	1	3	1	1	**2**
J58-J60	Publishing, audio-visual and broadcasting activities	4	4	3	3	**4**
J61	Telecommunications	4	4	4	4	**4**
J62-J63	IT and other information services	4	4	4	4	**4**
K	Financial and insurance activities	4	4	4	4	**4**
L	Real estate activities	1	1	1	1	**1**
M	Professional, scientific and technical activities	4	4	4	3	**4**
N	Administrative and support service activities	3	3	4	3	**3**

O	Public administration and defence; compulsory social security	2	1	4	4	**3**
P	Education	2	3	3	2	**3**
Q86	Human health activities	2	3	1	2	**2**
Q87-Q88	Residential care activities and social work activities without accommodation	2	3	1	2	**2**
R	Arts, entertainment, and recreation	2	3	3	1	**2**
S	Other service activities	4	4	3	1	**3**

Note: Authors' classification of industries as high (mean >2), medium (mean = 2) or low (mean = 1) digital, based on four criteria from Calvino et al (2018).