Organisational capital, ICT and productivity in the digital age

Authors:
Filippo Bontadini
LUISS University
Cecilia Jona-Lasinio
LUISS University
Giuseppe Nicoletti
LUISS Lab of Economics and Energy Transition

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Authors' contacts:
nicolettigiuseppe4@gmail.com

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Abstract

Intangible investments have been found to support aggregate labour productivity growth directly as a production input, as well as via interactions with new technologies. However, focus on the "organisational capital" (OC) component of intangibles has been scarce, partly due to lack of data. This study looks at how the complementarity between a specific subset of intangibles, OC, and ICT affects aggregate labour productivity outcomes, focusing on the distinction between own-account and purchased organisational expenses in digitally intensive industries. We leverage the EUKLEMS & INTANProd harmonised and fully integrated productivity database including all intangible components, with broad international, industry and historical coverage (Bontadini et al., 2023; Corrado et al., 2022a) to address this gap. Based on a sample of 10 OECD countries and 39 manufacturing and service industries over the 1995-2019 period, we find robust evidence that the productivity benefits of organisational expenses originate mostly from in-house buildup of such intangibles. These are more than twice as productive as purchased organisational services in our estimates and these results are magnified in industries that are relatively more digitally intensive. Crucially, we find evidence of production complementarities between organisational expenses and ICT intensity. Synergies between OC and ICT are driven mostly by investment in own-account organisational capital and are stronger in digitally intensive industries. Our results suggest that a better internal organisation of production is a key channel through which intangible investments affect productivity and that there are relevant complementarities between intangibles, new technologies and digital adoption. These results emphasise how investment in organisational capital can amplify the benefits of new technologies and digital tools, ultimately driving productivity gains.

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, 2017; 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 have been shown to be very sensitive to accounting for intangible investments in the estimation of production functions at both the firm and aggregate levels (Brynjolfsson and Hitt, 2000; Corrado et al., 2017). Further, the somewhat disappointing productivity effects of investment in digital technologies have been related to the time and expenses needed to build up the matching intangible capital, which delays technology diffusion and its corresponding benefits (Brynjolfsson 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 the productivity effects of various measures of total intangibles (e.g. Niebel et al., 2017; Roth and Thum, 2013; Corrado et al., 2022a) or on the effects of 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 both part of larger intangible aggregates – innovative property and economic competencies, respectively, using Corrado et al.'s (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.

This paper focuses on the productivity effects of an aggregate measure of organisational changes – the so-called "organisational capital" (OC) component of intangible assets according to Corrado et al. (2005) – which includes all expenses related to managerial tasks. Instead of using survey data on managerial skills, the paper takes a standard production function approach linking investment in organisational assets to productivity growth. Adopting this approach is appropriate because there can be important complementarities between managerial skills and the broader organisational investments that are captured by the aggregate measure of OC.

Following Corrado et al. (2005), a key distinction is made between expenses that build up firm-specific organisational know-how and purchases of organisational services that are supplied on the market (e.g. by management consulting firms or other professionals). As we discuss more at length in the next section, the effect on productivity performance likely differs depending on whether OC is acquired commercially by purchasing a temporary flow of intellectual services – whose contribution to long-lived organisational assets is uncertain – or generated within the firm – which results in a permanent flow of services that, *inter alia*, durably improves internal capabilities to absorb new technology.

Theory and evidence from the business management literature also suggest that OC is likely to be highly synergetic with ICT assets and digital technology adoption (Brynjolfsson and Hitt, 2000; Li et al., 2006), whose intensity is highly heterogeneous across industries. Indeed, OC buildup is both enabled by the use of these technologies in production and enables their adoption. It is important therefore to evaluate both potential synergies with ICT and differences in digital intensity across industries, to carefully assess the productivity effects of investing in OC.

Despite its potential importance for economic performance in the digital age, empirical research on the role of organisational capital (OC) remains limited, particularly at the aggregate level. This is partly due to the challenges in accurately measuring these assets (Black and Lynch, 2005). Furthermore, we are unaware of any research that examines the differential productivity effects of own-account versus purchased organisational capital and how these interact with digital technologies.

In this paper, we contribute to filling this gap by leveraging on new aggregate data on intangibles by Corrado et al. (2022a) (described in Bontadini et al., 2023), who not only explicitly measure OC at the detailed industry level but also distinguish between own-account and purchased components of these assets. The subsample of the data used in this study covers

39 manufacturing and service sectors in 8 major EU economies, the UK and the US over the 1995-2019 period.[1]

Our empirical analysis takes a two-pronged approach. First, we use these data to explore whether the effect of organisational capital (OC) on industry-level hourly productivity growth differs depending on the nature of OC expenditure. Then we check if the productivity impact of OC varies with the digital intensity of different industries, and whether ICT intensity has a mediating effect because of its complementarity with intangible assets. Throughout the analysis, we focus on the productivity effects of various types of capital controlling for other country and industry characteristics as well as economy-wide shocks, using the production model proposed by Corrado et al. (2017), which is estimated with both GLS and GMM to tame endogeneity issues.

Our results extend to the aggregate level past firm-level evidence concerning the OC-productivity nexus bringing additional insights on the parallel effects of digitalisation and organisational change on aggregate productivity, with brand new findings on the leading role played by own-account organisational assets. We show that increasing the stock of OC has a positive impact on productivity growth but the effects of increasing own-account OC are at least twice as large as those of increasing purchased OC, even in the most conservative estimates. Moreover, the relative advantage of own-account over purchased OC is magnified when we focus on industry sub-groups classified as highly digitally intensive by Calvino et al. (2018) and when we condition the productivity impact of OC on industry-specific ICT intensities, using an augmented production model. This confirms the strong synergies between OC and ICT found in previous firm-level research and brings fresh evidence on the leading role played by own-account OC in generating productivity returns from the use of digital technologies.

These findings provide novel empirical support to the notion that better internal organisation of production and sales (including managerial capacity, logistics and supplier and customer networks) and better ability to develop and adapt this organisation to a rapidly changing business environment are key channels through which intangible investments affect productivity in the context of the digital transformation.

[1] In doing so, we purposefully focus on digital technologies preceding the emergence of widely available AI-based large language models; this latest technological revolution has garnerd significant attention but current aggregate data does not allow consistent comparisons across countries and industries and we therefore leave this to further research.

In the next section we lay out the conceptual background for our analysis and our main contributions to research. The following two sections describe in detail the features of the data, the empirical approach and the main findings. The last section draws conclusions and policy implications.

2. Theoretical framework and contribution

A key contribution of our study is to exploit the distinction between own-account and purchased components of OC to test whether these different types of knowledge-based capital interact differently with digitalisation and the corresponding rapidly changing business environment. It is useful therefore to discuss the distinction between knowledge that is built within the firm rather than purchased on the market.

2.1 Organisational capital: purchased and own-account components.

The distinction between own-account and purchased components of OC is in line with a well-established literature on innovation and management studies that takes a resource-based view (RBV) of the firm (Barney, 1991; Teece et al., 1997; Kogut and Zander, 1992; Penrose, 1959). In this framework, firms are bundles of resources that are heterogeneous across firms and partially mobile. While the notion of resources includes all assets, capabilities, information and knowledge, chief among these ar*e dynamic capabilitie*s (Winter, 2003) that allow firms to "integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al. 1997, p.516).

The features of the firm-level capabilities identified by the RBV research are remarkably close to the salient traits of intangible assets identified and measured by Corrado et al. (2005) at the industry level: they are accumulated over time in upstream sectors, leading to strong path-dependency and they are often hard to imitate or transfer, due to their frequent firm-specificity and secrecy. Such capabilities can be accrued either internally or externally to the firm, depending on the features of the knowledge they contain (Caloghirou et al. 2004). Firms have to generate their own expertise, processes and methods, when the underlying knowledge is tacit, firm-specific and non-tradeable or not easily appropriable. Otherwise, for capabilities that are based on more general and codified knowledge, firms can rely on services sold on the market (e.g. consulting, platform and AI services, etc.). These two modes of knowledge acquisition are distinguished, captured and measured in the conceptual framework developed in Corrado et al. (2005) and recently implemented empirically by Bontadini et al. (2023). This framework distinguishes the own-account and the purchased components of organisational capital, corresponding to the two types of knowledge-based capabilities described above, respectively.

2.2 Organisational capital and technology.

The distinction between own-account and purchased OC is also important when investigating the nexus between OC, digital technologies and productivity. Given the dearth of literature and evidence on this specific issue it is hard to have clear-cut ex-ante hypotheses. However, own-account and purchased OC contain qualitatively different kinds of knowledge, therefore it is reasonable to expect that both will be necessary for firms to successfully adopt new digital technologies and efficiently manage the production processes.

The extensive literature on knowledge creation within the firm suggests that in-house knowledge is necessary for firms to successfully use external knowledge and technology (Grigoriou and Rothaermel, 2017). This also resonates with the more macro-level evidence on absorptive capacity, pioneered by Cohen and Levinthal (1990) and Griffith et al. (2003), which emphasises the importance for firms to build up their own R&D knowledge base to be able to absorb, assimilate and exploit external knowledge and technology. Our study is related to this literature but we focus specifically on the role of organisational capital, rather than R&D. This is in line with the RBV literature emphasising the relevance of organisational capabilities as a method for firms to create and incorporate new technologies.

Against this background, 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 firm-level studies focusing on the influence of various measures of organisational assets on performance. For instance, Tronconi et al. (2011) find high output elasticities to OC measured capitalising sales, distribution and administration (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. 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 organisational assets (decentralisation of production). Based on UK firm-level data, Crespi et al. (2007) also find that ICT and a measure of organisational 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 organising IT within the firm. Liu and Ravichandran (2007) find similar results based on a sample of on-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 organisational 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, as discussed in the previous section, is driving productivity growth and has the largest synergies with ICT. Thanks to the fine level of detail in our 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 organisational 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 organisational and tangible assets of the firm – including both IT and organisational 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 digitalisation 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). Leveraging on our data, we are the first to provide aggregate evidence for a large number of countries and industries that OC investment – especially its own-account component – is instrumental in raising productivity in industries with a high level of digitalisation.

3. Data and descriptive evidence

We rely on the 2023 release of the EUKLEMS & INTANProd data, for a subsample of countries[2] over the 1995-2019 period. As detailed in Bontadini et al. (2023), the dataset updates the widely used EUKLEMS data on production, value added and investment integrating them with estimates of intangible assets that are not included in national accounts, following the taxonomy put forward by Corrado et al. (2005).

Productivity

Our main variable of interest is labour productivity growth in the market sector (excluding agriculture), measured as real value added per hour worked, where value added is adjusted to consider the inclusion of non-national account intangible assets into our analysis as from EUKLEMS & INTANProd (Bontadini et al. 2023).

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

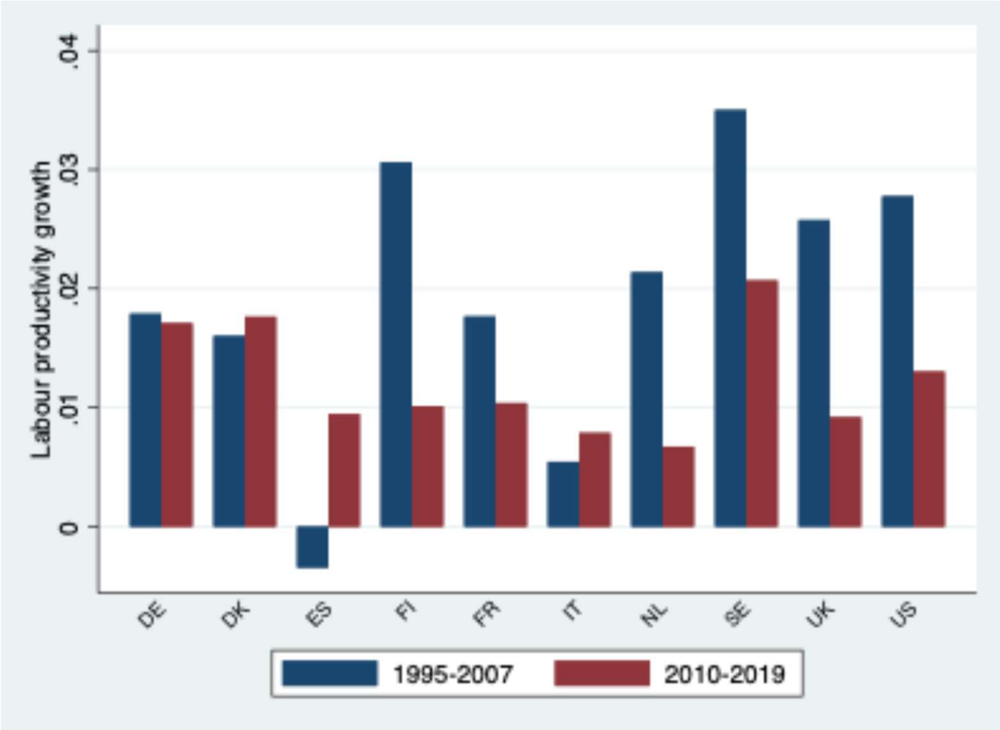


Figure 1. Average growth rates in adjusted chain-linked value added per hour worked, across countries over the 1995-2007 and 2010-2019 periods, in the market sector excluding agriculture.

Source: authors' calculations on EUKLEMS & INTANProd data.

Figure 1 reports the average productivity growth rate for the periods before and after the 2008 financial crisis for the countries in our sample. Consistent with the generalised productivity slowdown, countries that experienced the highest growth rates in labour productivity in the pre-crisis period – such as Sweden, the US, the UK and Finland – experienced a decline in the average rate of growth after the financial crisis. Italy shows very low productivity growth, in both periods, although with a slightly faster growth rate in the years following the financial crisis. Spain is the sole country with declining productivity before the financial crisis, characterised by relatively slow growth resuming afterwards. Germany and Denmark in contrast have increasing productivity rates both before and after the financial crisis.

Organisational capital and ICT

The 2008 System of National Accounts (SNA) recognises only a limited set of intangible assets: R&D, computer software and databases, mineral exploration, and artistic originals. Consequently, other intangibles identified by Corrado et al. (2005), such as design, advertising and market research (brand equity), training, and—crucially for this study—organisational capital (OC), are treated as intermediate expenditures.

For OC, 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 intermediate expenditures on managerial, legal and accounting services from the Supply and Use Tables compiled by Eurostat (and the Bureau of Economic Analysis for the US). It considers a fraction of these expenditures, adjusted to isolate the managerial component, as contributing to the buildup of long-lived organisational assets. The own-account component relies on a sum-of-cost approach, consistent with methods used by national statistical offices to estimate investment in computer software and databases. It is a fraction of wages paid to workers with executive occupations, which is assumed to reflect the part of their time used in building long-lived organisational assets. Both components of organisational capital cover mainly operating models (services of head offices and management consulting services). Additional details on the methodology and the data sources can be found in Bontadini et al. (2023).

By using distinct measures for investment in the purchased and own-account components, we are able to distinguish between two key ways in which companies, and industries at the aggregate level, accumulate OC. While these two kinds of investment are related, they involve different kinds of knowledge and capabilities that might influence productivity and interact with the acquisition of new technologies and the digitalisation process in different ways.

To capture industry-level ICT intensity, 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 country-specific total stocks of ICT assets by industry in each period. These stocks will then be averaged across countries in each industry and period to obtain an exogenous conditioning variable for the influence of OC in our regression models.

Figure 2 shows the dynamics of investment across ICT, intangible assets and OC, as a share of adjusted value added, at current prices. It 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 OC, notably Sweden, Denmark, France and the Netherlandss, suggesting that these two groups of assets are likely to move together. Furthermore, OC also accounts for a sizeable portion of investment in intangible assets, accounting for between 2 and 5 percent of adjusted value added.

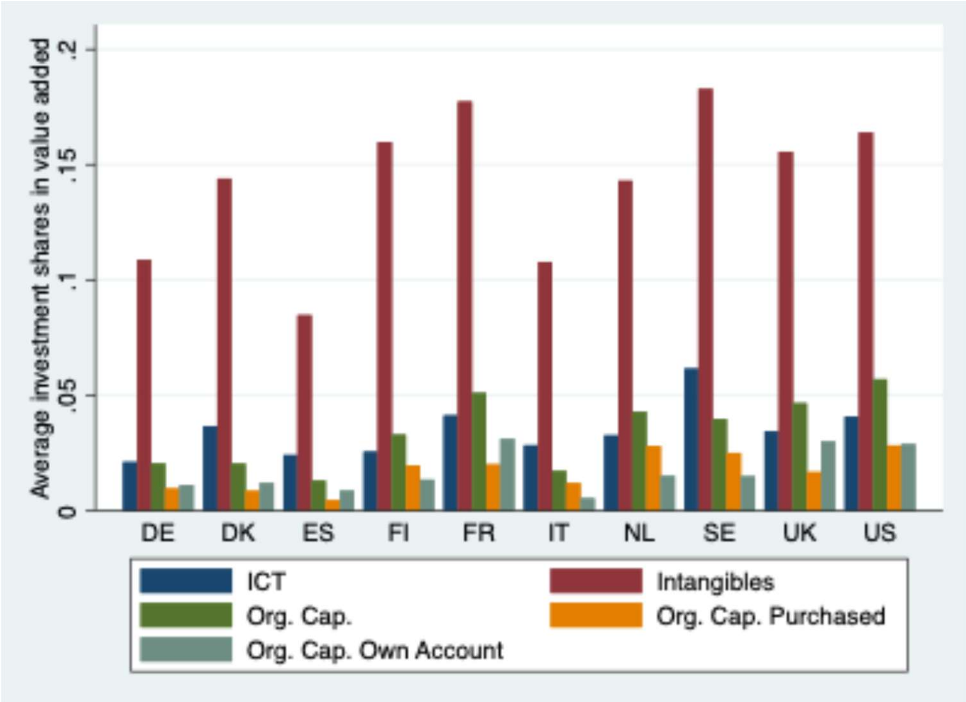


Figure 2. Investment in ICT and Organisational capital, breaking down purchased and own-account, as a share of adjusted value added at current prices in the market sector, excluding agriculture.

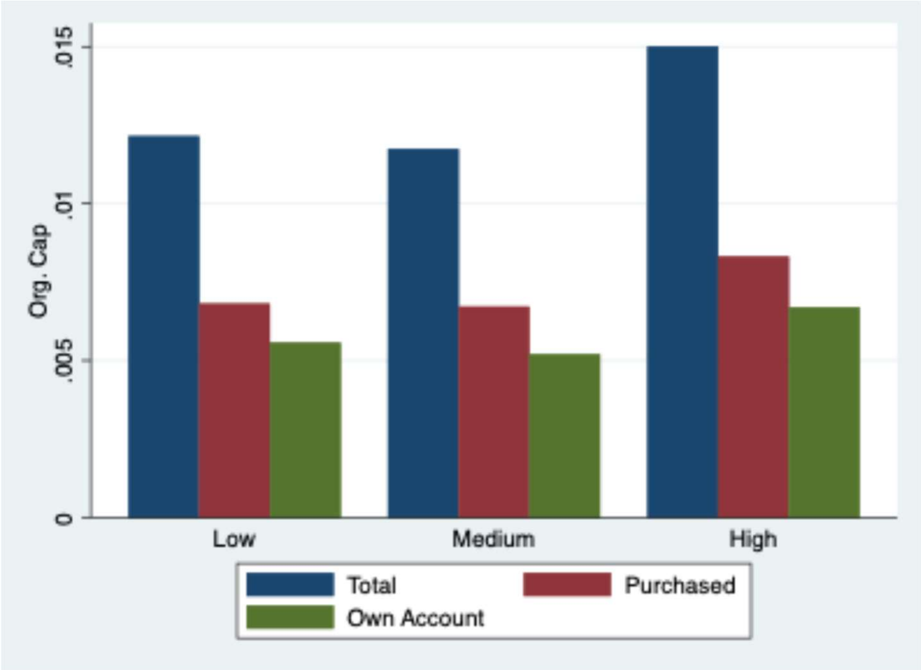
Source: authors' calculations on EUKLEMS & INTANProd data.

Figure 2 also shows that both own-account and purchased components account for a significant share of total investment in OC. We can also see differences in the shares of the two components across countries. For example, own-account OC is significantly larger than the purchased component in both France and the UK, while the opposite is true in Spain, the Netherlands and Sweden. Differences in the composition of OC could partly account for different productivity outcomes across countries.

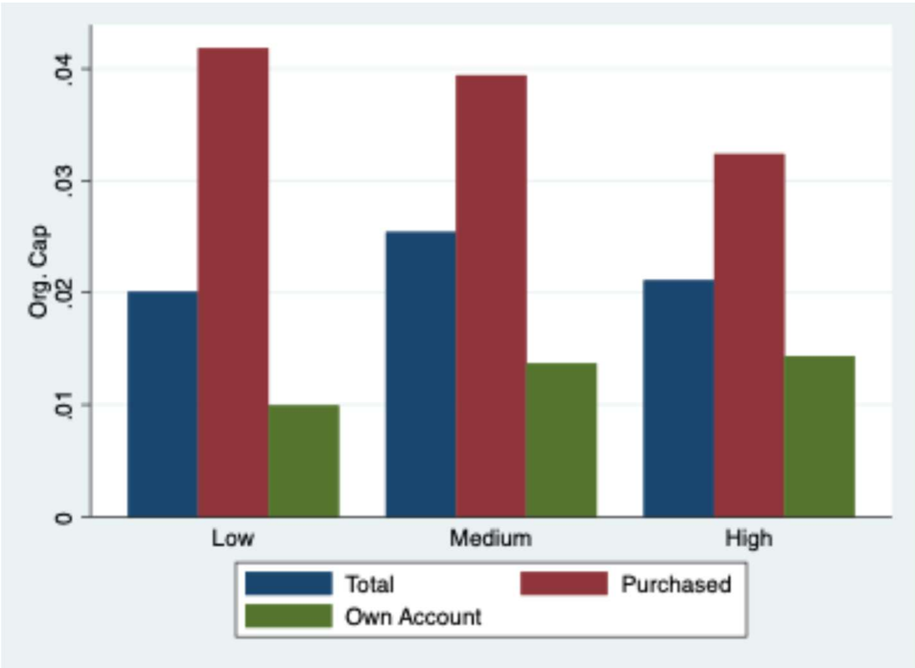
In order to further study the relationship between ICT and OC, we also explore how intensity in OC varies across industries, based on how digitally-intensive these are. In order to classify industries by their digital intensity, we use the taxonomy proposed by Calvino et al (2018), who rank industries in quartiles, according to multiple criteria. Here, we rank industries using only criteria that are applicable and available for all those included in our sample – namely (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 highly digitally intensive if the mean is above three, medium digitally intensive if it is around two and low digitally intensive otherwise (details can be found in Table A1 in the Appendix).

Once we have allocated each industry to one of the three groups, we look at the average stocks of organisational capital per hour worked and at constant prices both in levels and growth rates (Figure 3 Panel A and B, respectively). As expected, highly digitally intensive industries have also the highest intensity in organisational capital both when looking at the total and its two components separately (Panel A). Interestingly, low digital industries have, on average, larger organisational capital than medium digital ones.



(*A*)



(*B*)

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

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 highly digitally intensive industries. Thus, purchased and own-account OC components have rather different patterns not only across countries but also across industries classified by digital intensity, suggesting that the way they interact with ICT intensities and digitalisation could also be different. Overall, Figure 3 shows that the stock of organisational capital has grown faster in industries with lower average stocks, hinting at a convergence in the diffusion of organisational capital across industries.

Finally, before turning to econometric analysis, Figures 4 and 5 provide some *prima facie* evidence of the main relationships of interest. Figure 4 plots average labour productivity growth over the sample period against growth of the OC stock per hour worked and its two components, classifying industries by their digital intensity. Figure 5 instead plots average productivity growth against average stocks of OC classifying industries by their digital intensity.

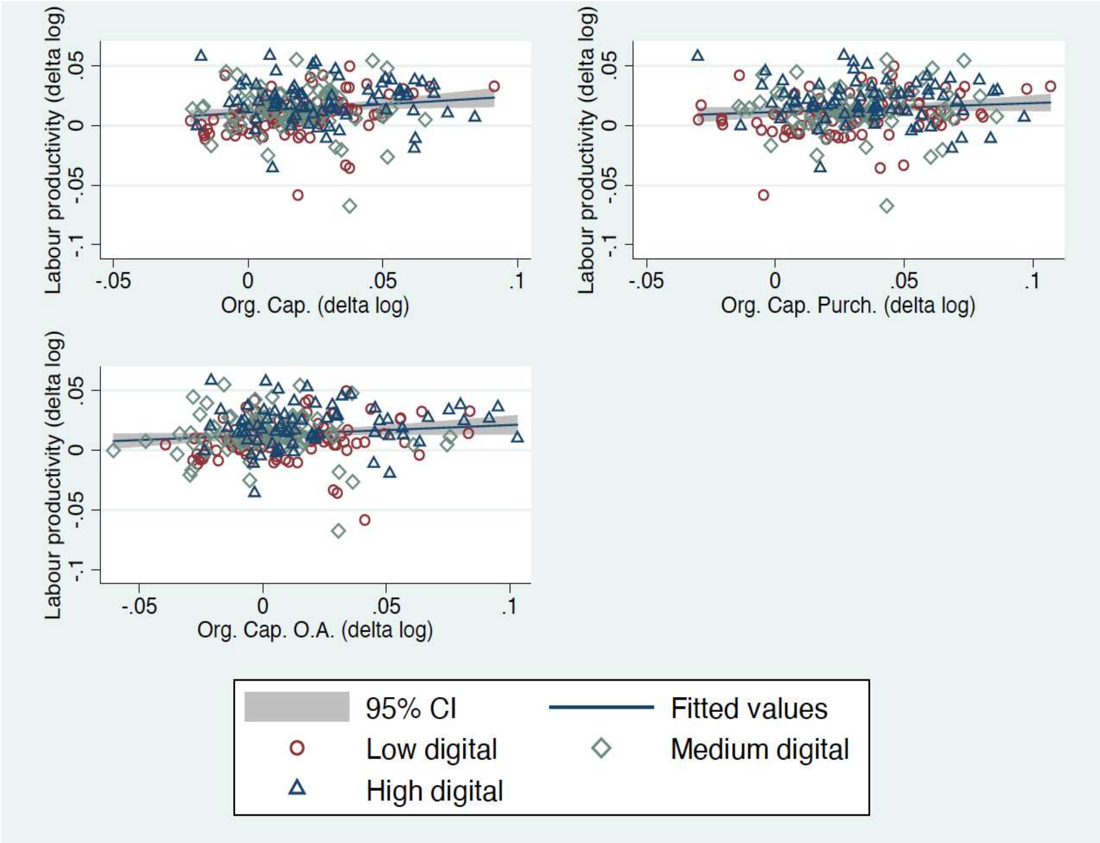


Figure 4. Growth in average hourly labour productivity vs investment in OC in the market sector excluding agriculture, by digital intensity

Source: authors' calculations on EUKLEMS & INTANProd data.

Note: Country-industry observations over the sample period.

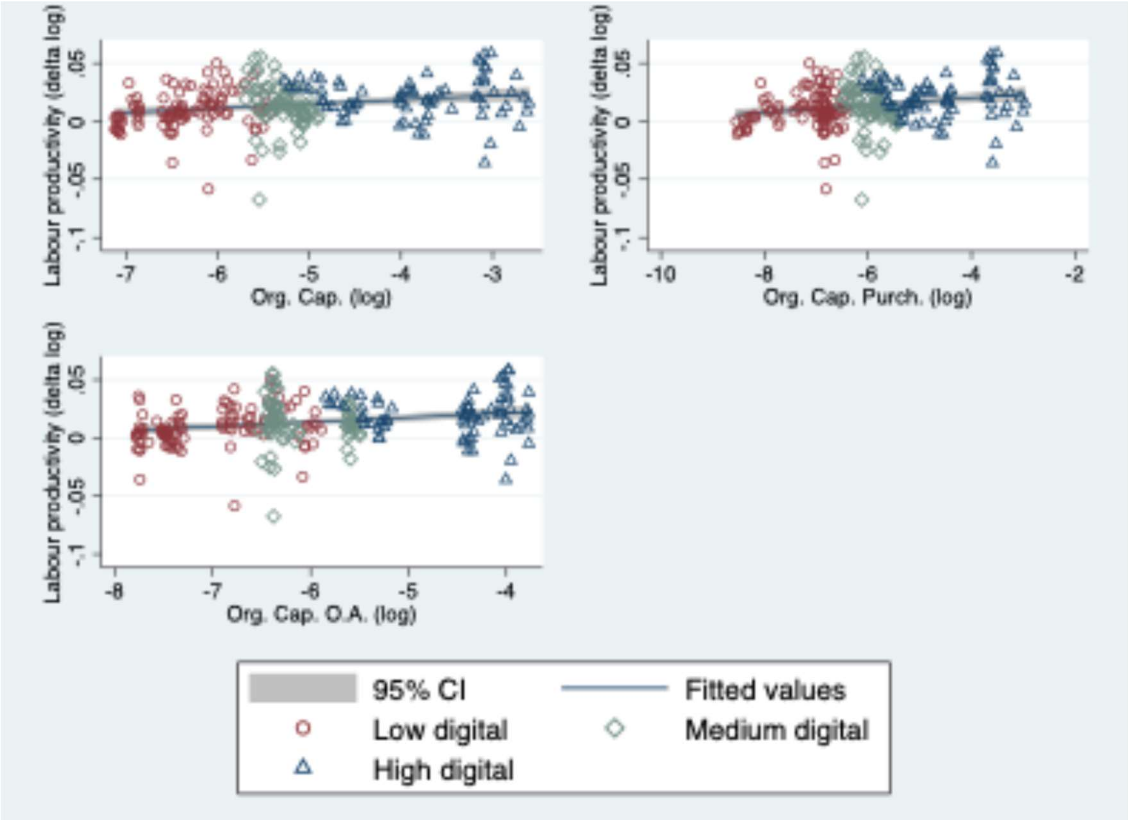


Figure 5. Growth in average hourly labour productivity vs the stock of OC in the market sector excluding agriculture, by digital intensity.
Source: authors' calculations on EUKLEMS & INTANProd data.
Note: Country-industry observations over the sample period.

All told, we find a positive and statistically significant relationship, suggesting that higher investment in OC and higher OC stocks are both associated with faster productivity growth. This appears to hold regardless of which component of organisational capital we look at, at least in terms of descriptive evidence. However, we do observe a clear distinction in terms of digitalisation level: highly digitally intensive industries have higher OC per hour worked and labour productivity growth. In order to ascertain the robustness of this relationship and investigate it in more detail, in the next section we estimate a production model that includes changes in capital per hour worked (across different asset groups), ICT intensities and levels of digital adoption, while controlling for possible confounding factors and reverse causality via both fixed effects and instrumental variables.

4. Empirical strategy and main findings

The production function model

To test our main conjectures concerning the differential effects of OC components on productivity growth and the interaction between investment in OC and digitalisation, we adopt a two-pronged empirical production function approach. First, we estimate a benchmark model in which we relate hourly labour productivity to factor inputs distinguishing tangible from intangible capital. Second, we augment this model by conditioning the productivity effects of intangibles on the accumulated stock of ICT, in the spirit of Corrado et al. (2017). Finally, we also check whether estimates change significantly when we focus on the subgroup of highly digitalised industries identified as in Calvino et al. (2018).

Our benchmark model is the following:

$$\Delta \ln\left(Y/H\right)_{ict} = \alpha_1 \Delta \ln\left(K^{I-OC}/H\right)_{ict} + \alpha_2\, \Delta\, ln\left(K^{T}/H\right)_{ict}$$

$$+ \alpha_3 \Delta\, ln\left(K^{OC}/H\right)_{ict} + \lambda_c + \lambda_{ct} + \lambda_{it} + + \lambda_t + \eta_{ict} \qquad \textbf{(1)}$$

where Y denotes value added adjusted to include intangible capital (as in Corrado et al. 2005, 2009); H is total hours worked; Y/H= hourly labour productivity, K^T= tangibles, K^{I-OC}=intangibles excluding OC, K^{OC}= OC, λ_k (k=c, t) are country and time fixed effects, λ_{kt} (k=c, i) are country and industry trends and η_{ict} is a random error. To test differential effects of own-account and purchased OC, we split K^{OC} into its two components. Furthermore, to test heterogeneity of OC effects across industries we estimate the model on both the whole set of 39 industries and on the subgroup of the highly-digitalised ones.

The augmented production function model

Corrado et al (2017) showed that ICT and intangibles are complements in a production process and that ICT productivity returns are enhanced by interactions with intangible assets. They test the complementary effect resorting to an augmented production function model with interactions à la Rajan and Zingales (1998). In this paper, we adopt a similar approach to investigate whether investment in OC yields higher productivity returns in industries that are more ICT-intensive. In keeping with our benchmark production function analysis, we also investigate if the synergies between ICT and OC vary across the purchased and own-account components of OC. To this end, we include among the explanatory variables ICT intensity as well as its interaction with investment in OC or its components. To avoid endogeneity issues and proxy for "typical" industry-specific ICT intensities, we take the average across countries and time of this intensity in each industry.

Thus, our augmented production function model is as follows:

$$\begin{aligned}\Delta \ln\left(Y/H\right)_{ict} = {} & \alpha_1 \Delta \ln\left(K^{I-OC}/H\right)_{ict} + \alpha_2\, \Delta\, ln\left(K^{T}/H\right)_{ict} + \\ & + \alpha_3 \Delta\, ln\left(K^{OC}/H\right)_{ict} + \alpha_4\ ln\left(K^{ICT}/H\right)_{i,avg} + \\ & + \alpha_5\ ln\left(K^{ICT}/H\right)_{i,avg} * \Delta\, ln\left(K^{OC}/H\right)_{ict} + \\ & + \lambda_c + \lambda_{ct} + \lambda_{it} + \lambda_t + \eta_{ict}\end{aligned} \qquad (2)$$

where $\ln\left(K^{ICT}/H\right)_{i,avg}$ is the log of ICT intensity of each industry (averaged across countries and time), measured as real ICT stock per hour worked in industry i. Here as well we split OC into its two components and focus on both the whole set of industries and on the subgroup of highly-digitalised ones – to test whether digitalisation affects the influence of the two components of OC on productivity, either directly or indirectly via the mediation of ICT intensity.

A characteristic of multiplicative interaction models is that they are symmetric with respect to the interacted terms. Thus the interaction variable in the augmented production function model does not imply anything for the causal relationship between investment in OC and the ICT stock (Brambor et al. 2006). We assume that the impact of the change in OC on productivity growth is conditioned (or mediated) by the amount of ICT in the industry. Therefore, we expect that the estimated output elasticity of OC increases with ICT intensity. If our assumption is correct, we should find that in equation (1) $\alpha_5 > 0$, indicating that industries experience relatively higher productivity growth when organisational capabilities complement ICT capital intensity.

Econometric issues

Before discussing our results it is worth noting that the models control for a number of potentially omitted or confounding factors via their rich fixed effects structure – which accounts for macroeconomic shocks common to all countries, time and industry-invariant country-specific characteristics (such as institutional features), country-wide trends (such as waves of deregulation or trade liberalization) and industry-specific trends (such as technological progress).

However, despite these controls, estimates could be affected by structural identification problems related to measurement error, multicollinearity, and endogeneity of factor inputs. We deal with these potentially important issues by estimating the models with both GLS and GMM (Ackerberg et al., 2015).[3]

Empirical results

Tables 1-3 show the estimation results of the benchmark and augmented production function models. All regressions include country and time fixed effects, as well as industry and country time trends, and are estimated both by GLS and GMM. Each model specification is estimated using both the OC aggregate and its two components – own-account and purchased. Models are also estimated on all industries as well as on industries that are defined as highly digitalised according to Calvino et al. (2018).

Overall, the production model is validated by the data, with output elasticities to capital inputs always positive and significant. In line with previous research, GMM estimates reveal that capital input endogeneity leads to substantial downward bias in the estimated elasticities of both tangible and intangible capital inputs. Point estimates of these elasticities suggest the existence of increasing returns to capital as their sum is well over unity (around 1.5 depending on estimates). Also consistent with earlier evidence, OC is estimated to provide a strong contribution to productivity growth, at least as strong as the contribution of all other intangibles together. Also noticeable, is the evidence that in all tables the overall impact of OC on productivity growth appears to be largely driven by highly digitally intensive industries, where coefficient estimates account for most of the effects observed in the market sector as a whole.

By and large, results concerning our variables of interest – OC, its two components and their interactions with ICT intensity – are consistent across the GLS and GMM approaches, at least as regards the signs and significance of their estimated coefficients. For the sake of simplicity, we focus our subsequent discussion of results concerning the (direct and indirect, via ICT) influence of OC components on productivity solely on GMM regression estimates, which control for the many sources of endogeneity that can mar the GLS estimates.

[3] We employ two-step efficient GMM (2SLS-GMM), where the endogenous regressors are instrumented using their own lagged values and different combinations of them. This is a lag-instrumented IV-GMM approach.

Table 1 – Benchmark production function model: testing differential effects of own-account and purchased OC components.

	(1) GLS	(2) GMM	(3) GLS	(4) GMM	(5) GLS	(6) GMM	(7) GLS	(8) GMM
Intangibles (excluding OC) per hour worked (dln)	0.0443***	0.257***	0.0525***	0.300***	0.0394***	0.155**	0.0464***	0.232***
	(0.00571)	(0.0939)	(0.00711)	(0.0523)	(0.00560)	(0.0627)	(0.00697)	(0.0425)
Tangibles (non-residential) per hour worked (dln)	0.198***	0.868***	0.194***	0.737***	0.170***	0.936***	0.167***	0.712***
	(0.0154)	(0.151)	(0.0187)	(0.0906)	(0.0155)	(0.177)	(0.0189)	(0.0887)
Purchased OC per hour worked (dln)					0.0513***	0.237***	0.0774***	0.0848**
					(0.00807)	(0.0811)	(0.0112)	(0.0366)
Own-account OC per hour worked (dln)					0.218***	0.540***	0.224***	0.430***
					(0.0171)	(0.154)	(0.0209)	(0.0904)
Organisational capital per hour worked (dln)	0.188***	0.386***	0.220***	0.444***				
	(0.0140)	(0.127)	(0.0181)	(0.0826)				
Constant	0.0104***	-0.0239**	0.0151***	-0.00618	0.0104***	-0.0165	0.0154***	-0.00778
	(0.00335)	(0.0111)	(0.00418)	(0.00754)	(0.00338)	(0.0111)	(0.00417)	(0.00700)
Observations	5,833	5,158	3,456	3,073	5,833	5,158	3,456	3,073
Digitalisation	All	All	High	High	All	All	High	High

All specifications include country and industry trends as well as country and year fixed effects, Heteroskedasticity robust standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

Consistent with our working hypothesis, Columns 6 and 8 of Table 1 suggest that own-account OC has a much larger influence on productivity growth than purchased OC, twice as large on average and five times as large in highly digitally intensive industries. To the best of our knowledge, this result is novel. It may reflect the observed tendency of large successful companies in highly-digitalised industries to internalise the production of organisational know-how and capabilities to better respond to rapid changes in the competitive and technological context. It may also indicate that, when OC is generated in this way, efficiency-enhancing knowledge spillovers on other firms in the same industry are more common – via imitation or transfers of organisational capabilities to suppliers and customers that are part of the same industrial ecosystem (e.g. networks of firms that contribute to or use the same digital platforms).

Turning to the augmented production function model, Columns 2 and 4 of Table 2 provide some empirical support to the idea that ICT and OC are complementary in production. As expected, in industries that are more intensive in ICT, productivity grows faster reflecting their higher technological content. However the novel results is that, irrespective of the level of digitalisation, in industries that are more ICT-intensive the influence of OC on productivity growth is also stronger than elsewhere. Put differently, as ICT endowments grow investing in organisational capabilities yields increasing productivity returns. One interpretation of these results is that investment or innovation in the way to organize production needs to be supported by the use of new technology in order to fully deploy its effects on production efficiency. Conversely, OC may boost the ability to absorb and adapt to new technologies. At the same time, a wide use of ICT across the industry can also facilitate the diffusion of organisational capabilities across networks of firms, thereby bringing industry-wide productivity benefits.

Table 2 – Augmented production function model: testing the mediating effect of ICT intensity on OC

	(1) GLS	(2) GMM	(3) GLS	(4) GMM
Intangibles (excluding OC) per hour worked (dln)	0.0415***	0.0606*	0.0531***	0.0975***
	(0.00559)	(0.0363)	(0.00726)	(0.0325)
Tangibles (non-residential) per hour worked (dln)	0.162***	0.196**	0.152***	0.265***
	(0.0156)	(0.0919)	(0.0192)	(0.0595)
Organisational capital per hour worked (dln)	0.341***	0.514**	0.422***	0.379***
	(0.0753)	(0.209)	(0.0888)	(0.136)
Industry average of ICT intensity	0.00877***	0.0115***	0.00873***	0.0112***
	(0.000670)	(0.00136)	(0.000775)	(0.00114)
Interaction of OC per hour worked (dln) and industry average ICT intensity	0.0238*	0.0596*	0.0355**	0.0410*
	(0.0122)	(0.0331)	(0.0153)	(0.0236)
Constant	0.0639***	0.0504***	0.0676***	0.0698***
	(0.00530)	(0.0121)	(0.00628)	(0.00923)
Observations	5,833	5,158	3,456	2,930
R-squared		0.069		0.235
Digitalisation	All	All	High	High

All specifications include country and industry trends as well as country and year fixed effects, Heteroskedasticity robust standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

This evidence is confirmed and strengthened when we distinguish own-account vs purchased OC (Table 3), though with an interesting twist. Columns 1 and 2 of Table 3 include both components of OC and their interactions with ICT intensity. In the GMM specification in column 2, the purchased component of organisational capital and its interaction with ICT intensity are no longer statistically significant, whereas the own-account component and its interaction remain positive and significant. In columns 3 to 6 we focus on the interaction between ICT intensity and own-account. These estimates confirm that the interaction between own-account OC and ICT intensity is positive and significant in both the full sample and highly digitally intensive industries. One interpretation could be that, while purchased OC does not generate efficiency gains beyond those ignited by investment in new technologies, own-account OC generates internal capabilities that yield such gains, especially in conjunction with the use of new technologies. [4]

This would be in line with the RBV literature that emphasises the importance of organisational resources built in-house, rather than purchased on the market, that are tacit and firm-specific and grant companies the ability to adapt to rapidly changing environments, i.e. dynamic capabilities, such as those characterised by rapid adoption of digital technologies.

All in all, our results support the idea, consistent with both the Resource Based View of the firm and theories of technology adoption and innovation, that own-account OC is more productive than purchased OC, especially so in a highly-digitalised environment. Results also support the idea that OC is complementary to the adoption of new technologies, yielding synergies that boost the productivity gains from investing in organisational capabilities. These synergies are found to be particularly evident for the own-account component of OC, which helps build up technology absorption capacity and the long-run capabilities to adapt to innovation and production reorganisation that are required during the digital transition.

[4] Another, more statistical, explanation could be that purchases of consulting services are typically more concomitant and endogenous to productivity developments than in-house buildup of such assets, which takes longer and is more conducive to long-term productivity improvements. Thus coefficient estimates of the impact of purchased OC may be more subject to simultaneity and endogeneity bias.

Table 3 – Augmented production function model: testing the mediating effect of ICT intensity on own-account and purchased OC

	(1) GLS	(2) GMM	(3) GLS	(4) GMM	(5) GLS	(6) GMM
Intangibles (excluding OC) per hour worked (dln)	0.0353***	0.0710*	0.0348***	0.0820*	0.0459***	0.0853***
	(0.00543)	(0.0410)	(0.00542)	(0.0428)	(0.00709)	(0.0330)
Tangibles (non-residential) per hour worked (dln)	0.137***	0.295***	0.136***	0.270***	0.127***	0.241***
	(0.0158)	(0.0736)	(0.0159)	(0.0783)	(0.0194)	(0.0497)
Industry average of ICT intensity	0.00918***	0.0109***	0.00887***	0.0105***	0.00891***	0.0115***
	(0.000693)	(0.00132)	(0.000646)	(0.00128)	(0.000747)	(0.00110)
Own Account OC per hour worked (dln)	0.554***	0.778***	0.534***	0.782***	0.477***	0.578***
	(0.0878)	(0.193)	(0.0861)	(0.186)	(0.0946)	(0.142)
Interaction of own-account OC per hour worked (dln) and industry average ICT intensity	0.0544***	0.101***	0.0509***	0.103***	0.0414**	0.0662***
	(0.0145)	(0.0295)	(0.0142)	(0.0284)	(0.0162)	(0.0243)
Purchased OC per hour worked (dln)	-0.0146	-0.0502	0.0459***	0.0233	0.0636***	-0.0102
	(0.0448)	(0.128)	(0.00841)	(0.0461)	(0.0112)	(0.0291)
Interaction of purchased OC per hour worked (dln) and industry average ICT intensity	-0.0103	-0.00766				
	(0.00738)	(0.0210)				
Constant	0.0664***	0.0796***	0.0645***	0.0763***	0.0689***	0.0749***
	(0.00544)	(0.0101)	(0.00520)	(0.00991)	(0.00619)	(0.00921)
Observations	5,833	4,917	5,833	4,917	3,456	2,930
Digitalisation	All	All	All	All	High	High

All specifications include country and industry trends as well as country and year fixed effects, Heteroskedasticity robust standard errors in parentheses - *** p<0.01, ** p<0.05, * p<0.1

5. 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 organisational 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 the nature of organisational capital, industry ICT intensity and the level of digitalisation, distinguishing between own-account and purchased organisational assets.

Extending previous firm-level results, we find that organisational capital brings sizeable aggregate productivity gains and that gains are higher in highly digitalised and ICT-intensive industries, suggesting industry-wide synergies between these technologies and the accumulation of organisational knowledge. While investing in organisational capital is found to bring productivity benefits to both high and low digitalised industries alike, most of the productivity impact of OC originates from highly-digitalised industries. Crucially, both productivity gains and synergies with new technologies appear to be mostly related to the accumulation of internal knowledge via own-account investments, which we consider to be the main finding of the paper. This can be related to the greater potential that such investments have for increasing the long-run absorptive capacity, adaptability and resilience of firms to technological progress as well as to potentially larger spillover effects of the corresponding knowledge creation at the industry level.

Our results also aim to spur more research to test their robustness, better understand the channels and extend the analysis in several directions. Especially, the interaction between investment in organisational 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 organisational 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 organisational 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 in-house organisational 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 (Giorcelli, 2019, and Bianchi and Giorcelli, 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 organisational know-how within firms can be very effective in improving efficiency and performance.

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Appendix – Table A1

		Digitalisation criteria				
Industry	Industry description	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).