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New Evidence on Intangibles, Diffusion and Productivity

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This paper presents new evidence on the impact of intangible capital on productivity dispersion within industries. It first shows that rise in productivity dispersion after 2000 is more pronounced in intangible-intensive industries; then analyses the link between intangible capital intensity and productivity dispersion both at the top and at the bottom of the productivity distribution, and in different industries. The findings suggest that industries that have experienced a stronger increase in intangible investment have also seen a steeper rise in productivity dispersion both at the top and at the bottom of the productivity distribution. While the results at the top seem to be associated with the scalability of intangible capital – which is likely to disproportionally benefit high-productivity firms and incumbents – dispersion at the bottom appears to be linked to complementarities between intangible investment and factors like digital intensity, trade openness and venture capital.

Keywords: Innovation, Investment, Science and Technology

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Executive Summary

The last two decades have been characterised by a slowdown in productivity growth and a simultaneous increase in productivity dispersion between firms. At the same time, intangible assets, such as data, proprietary software and human and organisational capital have been increasingly recognised as key drivers of productivity growth. Thus, intangible capital has also been put forward as one potential factor contributing to the increasing productivity dispersion between firms within industries.

This report contributes to this discussion by combining, cross country data on productivity dispersion within industries with cross-country data on sectoral level intangible investment. This novel data allows for the first time, a detailed analysis of intangible investment as a driver of productivity dispersion and implications for policies for ten countries.

The report provides several key takeaways:

- First, industries with higher levels of intangible investment experienced higher increases in productivity dispersion between firms. On average, in the preferred specification, an increase in intangible investment of 10 percentage points is linked to an approximately 1.5 percentage point increase in productivity dispersion. While the identification strategy does not allow to establish causality, the correlation between intangible investment and productivity dispersion is robust to controlling for average firm size , proxied by either average gross output, capital or labour input, and for capital intensity and to controlling for the dispersion in these respective measures, as well as to different specifications of fixed effects, different definitions of productivity dispersion and separate analysis of individual macro sectors.
- Second, the divergence between frontier firms and the median firm in an industry can at least in part be attributed to the scalability nature of intangibles, as the link between dispersion at the top (i.e. between firms at the 90th percentile and the median) and intangibles is stronger in industries where differences in sales across firms are larger.
- Third, the estimates suggest that the diffusion of digital technologies to the least productive firms within industries is harder the higher the intangible intensity of the sector considered and intangible investment is found to be linked to a significant increase in the productivity dispersion at the bottom (i.e. between firms at the 10th percentile and the median firm within an industry). These results point to the existence of complementarities between intangible assets and digital technologies: as digital technologies necessitate complementary investments in intangibles, laggard firms - which are unable to carry out the necessary intangible investment - fall behind in digital intensive sectors.
- Finally, and importantly for policy makers, the results presented in this report suggest that the link between intangibles and productivity dispersion varies significantly across sectors and countries, along different structural characteristics such as digital intensity, trade openness and availability of financial resources (e.g. venture capital). This may offer valuable evidence-based insights into potential areas for policies aiming at alleviating lags in diffusion and enhance productivity growth across the board.

Taken together, the results help identify several policy areas that have the potential to help lagging firms close the gap with leading firms by investing in intangible assets and benefitting from the adoption of new technologies. When designing policies aimed at improving productivity performance across the board, it is very important to both continue fostering the innovative activity of the most productive firms, and at the same time strengthening the ability of the economy to diffuse innovation to as many firms as possible. Indeed, the report's analysis suggest that policies that encourage intangible investment by laggard firms likely alleviate the heterogeneous gains from the digital transformation due to complementarities between intangibles and digital technologies, and might ensure that the benefits of the digital transformation are shared more widely.

This report fits into a larger agenda of policy analysis conducted within the OECD, which investigates the rising importance of intangible assets and their complementarities with digital technologies in modern globalised economies from different angles. Related research has shown that industries tend to become more concentrated as their intensity in intangible capital rises (Bajgar, Criscuolo and Timmis, forthcoming[1]), tend to experience rising and diverging firm-level markups (Calligaris, Criscuolo and Marcolin, 2018[2]) and sharper decline in entry rates (Calvino and Criscuolo, 2019[3]).

1. Introduction

The recent productivity slowdown has been accompanied by increasing productivity dispersion in many countries. Recent empirical studies of productivity using micro-level data have indeed emphasised an increase in productivity heterogeneity over time within narrowly-defined industries at the level of individual countries (Cette, Corde and Lecat, 2017[4]) and across countries (Andrews, Criscuolo and Gal, 2016[5]; Berlingieri, Blanchenay and Criscuolo, 2017[6]; Berlingieri et al., 2020[7]; Gal et al., 2019[8])

Debates amongst economists suggest that the recent COVID crisis might have accelerated the current diverging trends and amplified productivity gaps across firms. Recent OECD work for example highlights the differences across firms to implement teleworking during phases of lockdowns and restrictions to free movement "may well have exacerbated existing inequalities" (OECD, 2020[9]), as well as the higher vulnerability and lower resilience of small and medium-sized enterprises (SMEs) (OECD, 2020[10]) and start-ups (OECD, 2020[11]).

While productivity dispersion is not negative per se, empirical evidence suggests that the recent increase in dispersion may be a manifestation of a decreased diffusion of innovation from frontier firms to followers, less productive firms (Berlingieri, Blanchenay and Criscuolo, 2017[6]; Andrews, Criscuolo and Gal, 2016[5]; Akcigit and Ates, 2019[12]), and that within countries many existing technologies may remain unexploited by a large share of firms in the economy (Comin and Mestieri, 2018[13]).

The availability of digital technologies and the rising "intangibility" of production might have had the potential to contribute to widespread growth and improvement in performance, given: i) improved real-time measurement of business activities; ii) faster and cheaper business experimentation; iii) more widespread and easier sharing of ideas; and iv) the ability to scale up innovations with greater speed and fidelity (Brynjolfsson and McAfee, 2011[14]).

However, growing empirical evidence suggests also that the digital transition and the increased importance of intangible capital as factor of production might be the reason for increasing dispersion in firm performance (Crouzet and Eberly, 2019[15]; Akcigit and Ates, 2019[12]; Haskel and Westlake, 2017[16]; Gutiérrez and Philippon, 2017[17]).

The rising importance of intangible capital - such as research and development (R&D), data, proprietary software and human and organisational capital - as a source of growth in the digital and knowledge economies might have contributed to slower diffusion (Andrews and Criscuolo, 2013[18]; Andrews and de Serres, 2012[19]; Haskel and Westlake, 2017[16]; Corrado, Hulten and Sichel, 2005[20]; Corrado, Hulten and Sichel, 2009[21]; Corrado and Hulten, 2010[22]; Van Ark, 2015[23]). In particular, R&D is known to play a decisive role in determining differences in productivity across firms and productivity growth (Doraszelski and Jaumandreu, 2013[24]) and intangible assets, which are often proprietary (Bessen, 2017[25]) and costly to replicate, are complementary to tangible digital assets. The delay in the realisation of investments in these assets might indeed help explain the observed productivity slowdown (Brynjolfsson and McAfee, 2011[14]; Brynjolfsson, Rock and Syverson, 2017[26]). In digital intensive industries, the lower accumulation of intangible capital of laggard firms, due to its costly and slow implementation, has been found to act as an impediment to their catch-up (Brynjolfsson, Rock and Syverson, 2019[27]; Crass and Peters, 2014[28]). More broadly, the decline in knowledge diffusion between frontier and laggard firms has been put forward as a driver of productivity dispersion and declining business dynamism (Akcigit and Ates, 2019[12]).

While empirical evidence on the effect of intangibles on productivity growth is widespread across the globe (Barnes and McClure, 2009[29]; Baldwin, Gu and Macdonald, 2012[30]; Corrado et al., 2012[31]; Chen, Niebel and Saam, 2016[32])[1], the rising importance of intangible capital has also been put forward explicitly as one potential factor contributing to the increasing productivity dispersion between firms within industries (Haskel and Westlake, 2017[16]) but empirical evidence of this link remains scarce.

Theoretical papers, such as Aghion et al. (2019[33]) and De Ridder (2019[34]), suggest theoretical mechanisms whereby the rise in the importance of intangible capital could be a key factor contributing to the increased productivity dispersion between firms,.

There might be multiple mechanisms underlying the relationship between increased use of intangibles and the increase in productivity dispersion. On the one hand, as suggested by De Ridder (2019[34]), some firms may use their greater efficiency in using intangible inputs to undercut their competitors on price, which in turn enables them to hold on to market leadership and deter innovation from entrants or even prevent potentially innovative firms from entering the market altogether. In this setting, intangibles would lead to both a decrease in productivity growth and an increase in productivity dispersion. This may be due to increased market power of firms that are efficient at exploiting intangible capital and reflect the lower overall level of innovation resulting from these firms being able to undercut innovative entrants on price. On the other hand, intangible capital could be a factor that helps reduce the fixed cost of running multiple product lines. By reducing this cost, intangibles can help high productivity firms expand by innovating on more product lines, thus increasing productivity dispersion within industries, as described in Aghion et al. (2019[33]).

This report aims at contributing to this growing literature by providing novel insights on the relationship between intangible investment and productivity patterns and offering a deeper empirical investigation of the contribution of intangible investment to productivity dispersion thus supporting also the identification of policy measures favouring the spread of the benefits of innovation to as many firms as possible.

In particular, the report explores the relationship between productivity dispersion within narrowly defined industries and intangible investment in a cross-country setting. Combining the OECD MultiProd data on productivity dispersion within industries with cross-country sectoral intangible investment data from INTAN-Invest@2018, the analysis covers ten countries and 34 industries over the years 2000-2015. This goes beyond previous research on the topic, which used either country level data on intangible capital (van Ark et al, 2009; (Corrado, Haskel and Jona-Lasinio, 2017[35]; Van Ark et al., 2009[36]), or was limited to industry level analysis of individual countries (Crouzet and Eberly, 2019[15]; Haskel and Westlake, 2017[16]).

In addition, relative to other analysis, based on commercial databases covering listed companies only or only part of the firm population, this report relies on the OECD MultiProd dataset, which is based on the full population of firms (or a representative re-weighted sample) in most sectors of the economy. This feature is particularly important for the purpose of this work: MultiProd is one of the few datasets to include the population of firms for such a large number of countries and, hence, suitable for a cross-country analysis not only of innovative frontier firms, but also of less productive firms that might struggle to invest in intangibles and adopt new technologies. It collects micro-aggregated firm-level data on different features of the productivity and wage distribution for the entire economy in more than 25 countries over the period 1994-2015.

For the purpose of this report, intangible capital is defined according to the definition used in the INTAN-Invest data, which distinguishes between three categories of intangible capital: (i) innovative property – which comprises R&D, mineral exploration, entertainment and artistic originals, new products/systems in financial services, design and other new products/systems – (ii) digitized information like software and databases, and (iii) economic competencies, which include advertising, market research, employer-provided training, and organisational structure.

The main results of the analysis suggest a statistically significant correlation between intangible investment and productivity dispersion at the industry level. More precisely, industries with higher levels of intangible investment experienced higher increases in productivity dispersion between firms. On average, an increase in intangible investment of 10 percentage points is associated to an approximately 1.5 percentage point increase in the productivity difference between firms at the 90th and the 10th percentile of the productivity distribution. While the identification strategy does not allow to establish causality, the correlation between intangible investment and productivity dispersion is robust to the inclusion of control variables for average size of firms, such as average gross output, capital and labour inputs, and capital intensity and to controlling for the dispersion in these respective measures, as well as different specifications of fixed effects, different definitions of productivity dispersion and separate analysis of individual macro sectors.

One of the most important differences between intangible and tangible capital is that intangibles are highly scalable, which means that they can be duplicated at very low marginal costs (Haskel and Westlake, 2017[16]). This could contribute to productivity dispersion within industries, because firms that are already large could more easily finance the initial sunk cost of intangible investment and then benefit from the gains related to scalability. The report contributes to this argument by providing evidence of size effects of intangible investment that would be coherent with scale effects (although the measurement of productivity in this report does not allow to conclusively distinguish between economies of scale and size effects due to the omission of intangible investment in the productivity measure): the gap between firms at the 90th percentile and the median is correlated more strongly with intangible investment in industries with larger dispersion of gross output and firm age. [1]

Importantly for policy makers, our results suggest that the link between intangibles and productivity dispersion varies significantly across sectors and countries, along with different structural characteristics such as digital intensity, trade openness and availability of finance (e.g. venture capital). This may offer valuable evidence for potential policy measures aiming at alleviating lags in diffusion and enhance productivity growth across the board.

The econometric analysis suggests a positive and statistically significant relationship between intangible investment and the diffusion of digital technologies (measured by several indicators of information and communication technology [ICT] intensity at the industry level) to the least productive firms within industries. Intangible investment is found to be linked to a significant increase in the productivity dispersion between the

[1] This finding is in line with recent empirical contributions such as Lashkari, Bauer and Boussard (2018[37]), who find that bigger firms invest a higher share of their sales in intangibles capital. In similar studies, McKinsey (2018[38]) show that the most profitable firms invest more in software and R&D. Bessen (Bessen, 2019[39]) provides sector-level evidence that industries with higher IT intensity experienced higher growth in the sales share of the largest firms and highlights the scalability of intangibles as an advantage for firms that are already large (Bajgar, Criscuolo and Timmis, forthcoming[1]).

median firm and firms at the bottom of the distribution (10th percentile). We interpret this result as supportive of the existence of complementarities between intangible investment and digital technologies, in line with the literature cited above: as digital technologies necessitate complementary intangible investment, laggard firms which are unable to carry out the necessary intangible investment fall behind, the more so the more digital intensive the sector they operate in. These findings are also coherent with the results in Berlingieri et al. (2019), who find that laggard firms catch-up to the productivity frontier at a relatively lower speed in more digital and more knowledge intensive industries.

Furthermore, distinguishing between different categories of intangible investment reveals that investment in economic competencies, such as marketing and organisational capital, is the main driver of productivity dispersion both at the top and at the bottom, while innovative property as well as software and database investment provide a relatively smaller contribution. This aligns with other recent studies underlining the importance of economic competencies for productivity growth (Roth and Thum, 2013[40]; Piekkola, 2020[41]; Eisfeldt and Papanikolaou, 2014[42]), and, more generally, the contribution of management practices to firm productivity (Bloom and Van Reenen, 2007[43]; Syverson, 2011[44]; Bloom, Schankerman and Van Reenen, 2013[45]).

The report also provides supporting evidence that access to credit and R&D grants and tax credits may help reduce the financial frictions laggards face when adopting new technologies, often because of the necessary complementary investments in intangibles cannot be used as collateral.

Taken together, the results help identifying several policy areas that have the potential to help lagging firms close the gap with leading firms, invest in intangible assets and benefit from the adoption of new technologies. When designing policies aimed at improving productivity performance across the board, it is very important to continue fostering the innovative activity of the most productive firms, and at the same time strengthen the ability of the economy to diffuse innovation to as many firms as possible.

Intangibles are necessary to reap the full productivity effects of digital technologies. Appropriate policies facilitating intangible investment by laggard firms may therefore alleviate the heterogeneous gains from the digital transformation, and could ensure that its benefits are shared more widely. Facilitating these complementary investments through easier access to credit, venture capital or direct and tax funding of R&D has the potential to decrease asymmetries between firms in their ability to incur the initial sunk costs of intangible investment, and benefit from the scalability of intangibles.

This report fits into a larger agenda of policy analysis conducted within the OECD, which investigates the rising importance of intangible assets and their complementarities with digital technologies in modern globalised economies from different angles. [2]

The report is structured as follows: section 2 describes the two unique datasets underlying the analysis, MultiProd and INTAN-Invest, section 3 presents descriptive evidence on the patterns of productivity dispersion and intangible investment over the 2000-2015 period, and section 4 illustrates the framework underlying the empirical analysis. Section 5

[2] Related research has shown that industries tend to become more concentrated as their intensity in intangible capital rises (Bajgar, Criscuolo and Timmis, forthcoming[1]), tend to experience rising and diverging firm-level markups (Calligaris, Criscuolo and Marcolin, 2018[2]) and sharper decline in entry rates (Calvino and Criscuolo, 2019[3]). Research on the financing of intangible capital shows that financing frictions explain 14% of the variation in productivity across firms in intangible-intensive sectors (Demmou, Stefanescu and Arquie, 2019[46]; Demmou, Franco and Stefanescu, 2020[47])

presents the main empirical findings and the many robustness checks conducted, while Section 6 concludes.

2. Data

This section provides an overview of the data used, as well as of the main measure of productivity (multi-factor productivity) and "intangible capital" adopted in this report. Further details on the MultiProd project and the methodology adopted can be found in Berlingieri et al. (2017[6]) while for intangible investments in Corrado et al (2016[48]).

2.1. The MultiProd dataset

The analysis conducted in this report relies on the work undertaken in the last few years within the OECD "MultiProd" project. The implementation of the MultiProd project is based on a standardised STATA® routine that micro-aggregates confidential firm-level data from production surveys and business registers, via a *distributed microdata analysis*. This methodology was pioneered in the early 2000s in a series of cross-country projects on firm demographics and productivity (Bartelsman, Scarpetta and Schivardi, 2003[49]; Bartelsman, Haltiwanger and Scarpetta, 2009[50]). The OECD currently follows this approach in three ongoing projects: MultiProd, DynEmp, and MicroBeRD.[2] and extends it to matched employer-employee data in two new projects: LinkEED and the Human Side of Productivity (HSP). The distributed micro-data analysis involves running a common code in a decentralised manner by representatives in national statistical agencies or experts in governments or public institutions, who have access to the national micro-level data. The centrally designed, but locally executed, program codes generate micro-aggregated data, which are then sent back for comparative cross-country analysis to the OECD.

The advantages of this novel data collection methodology are manifold. It puts a lower burden on national statistical agencies and limits running costs for such endeavours. Importantly, it directly uses national micro-level representative databases, while at the same time achieving a high degree of harmonisation and comparability across countries, sectors, and over time.

The MultiProd program relies on two main data sources in each country. First, administrative data or production surveys (PS), which contain variables needed for the analysis of productivity but may be limited to a sample of firms. Second, business registers (BR), which contain a more limited set of variables but for the entire population of firms. The program works also in the absence of a business register, which is not needed when administrative data on the full population of firms are available. However, when data come from a PS, the availability of the business register substantially improves the representativeness of results and, thus, their comparability across countries.[3]

Census and administrative data, indeed, normally cover the whole population of businesses with at least one employee. Still, these datasets do not always exist or include all the information needed to calculate productivity. In these cases PS data need to be used. One of the big challenges of working with firm-level production surveys is that the selected sample of firms might yield a partial and biased picture of the economy. Whenever available, BRs, which typically contain the whole population of firms, are therefore used in MultiProd to compute a population structure by year-sector-size classes. This structure to re-weight data contained in the PS in order to construct data that are as representative as possible of the whole population of firms and comparable across countries.[4]

At the time of writing, more than 20 countries have been successfully included in the MultiProd database.[5] For most countries the time period spans from early 2000s to 2015. For Chile, Austria and Switzerland the time horizon is shorter (starting in 2005, 2008 and

2009 respectively), whereas for Finland, France and Norway data are available at least since 1995.

MultiProd collects data for all sectors of the entire economy, whenever available. However, in some parts of the econometric analysis in this paper the sample is restricted to manufacturing and non-financial market services.[6] Data in MultiProd are collected at the SNA A38 level.

2.2. Measure of productivity

The measure of productivity dispersion used in the econometric analysis is based on the multi factor productivity (MFP) indicator generated in MultiProd. In particular, the MFP measure is estimated econometrically at the firm-level using the Wooldridge (2009[51]) control function approach with value added as a measure of output. Firms are assumed to have a Cobb-Douglas production function, but not necessarily constant returns to scale:

$$Y_{it} = A_{it} K_{it}^{\sigma_K} L_{it}^{\sigma_L}$$

where A_{it} , firm *i*'s MFP at time *t*, is typically unobserved and has to be estimated. Y_{it}, K_{it} and L_{it} are value added, capital and labour inputs respectively.[7] The Wooldridge (2009[51]) procedure relies on estimating variable inputs with a polynomial of lagged inputs and a polynomial of intermediates. It allows for the identification of the variable input and yields consistent standard errors.

2.3. Data on intangible investments and capital stock

Measuring intangible capital involves expanding the core concept of business investment in national accounts by treating much business spending on "intangibles" – digital databases, R&D, design, brand equity, firm-specific training, and organisational efficiency – as investment (Corrado, Hulten and Sichel, 2005[20]). When this expanded view of investment is included in a sources-of-growth analysis, intangible capital is found to account for one-fifth to one-third of labour productivity growth in the market sector of advanced economies.

This report uses industry-level data on intangible and tangible investment from the INTAN-Invest database described by Corrado et al. (2016[48]). INTAN-Invest provides harmonised information for A21 NACE Rev 2 industries (see Appendix Table 1 for list of sectors) for 15 European countries and the United States for the period 1995-2015.

The country coverage of MultiProd and INTAN-Invest overlaps for ten countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands and Portugal) that will be the focus of this report.[8] Intangible investment are grouped under three broad categories: innovative property, computerised information and economic competencies. Table 1 summarises the components of these categories and the average share of each of them in total intangible investment for the estimation sample.

Table 1. Categories of intangible investment in INTAN-Invest

	Share in total intangible investment	Components
Innovative property	52%	R&D (scientific); Mineral exploration; Entertainment and artistic originals; New products/systems in financial services; Design and other new products/systems
Computer and Software Investment	14%	Software; Databases
Economic competencies	34%	Advertising; Market research; Employer-provided training; Organisational structure

Source: Corrado et al. (2012) and authors' calculations of shares in the estimation sample

Table 2. Categories of intangible investment

Categories	Types of Intangible Investment	Examples of Intangible Assets
(1)	(2)	(3)
Digitized Information	Software Databases	Digital capabilities, tools Trade secrets (data)
Innovative Property	Research and development (R&D) Mineral exploration Entertainment, artistic, and literary originals (E&AO) Other new product development (e.g., design originals, new financial products)	Patents Mineral rights Licenses, contracts Copyrights Attributed designs Trademarks
Economic Competencies	Branding Marketing research Organizational structure/business process investment Employer-provided training	Brand equity Market insights, customer lists Operating models, processes and systems (see note) Firm-specific human capital

Source: This paper and Corrado (2020), based on Corrado, Hulten and Sichel (2005) Note. Operating models include customer platforms, supply chains, distribution networks and after-market services

Table 2 summarizes the components in the expanded investment framework. Column 1 lists three broad types of outlays that have been identified as intangible investments: digitized information, innovative property, and economic competencies. Column 2 lists investments in specific assets that can be measured and tracked using the framework. Although the fixed asset boundary in national accounts has been expanded in recent decades to better account for the role of intangibles (e.g., R&D has been capitalized in national accounts beginning 2013 in the United States, 2014 in most European countries, and 2016 in the People's Republic of China and Japan), SNA-based national accounts still only capitalize software and databases, R&D, mineral exploration, and entertainment, literary and artistic originals.

Box 1. Different approaches to measuring intangibles

There are a number of ways of measuring intangibles (the below is based on (Lev 2001; Haskel and Westlake 2017).

One way of measuring intangibles is based on company accounts. Broadly speaking, accounting rules treat intangibles as assets if they are purchased (e.g. a patent or a customer list), while treating intangibles as expenses if they are internally generated. While exceptions to this rule exist, they tend to be rare. For example, internally generated software or R&D spending can be treated as asset investment under special circumstances, essentially when such spending is on a proven process, such as the last development stages of an already-proven R&D project or software tool.

There are of course a lot of complications over and above these general principles. First, in company accounts intangible assets are often split into "intangible other than goodwill" and "goodwill" (see e.g. the UK FRS102). The "Other than goodwill" group is then split between assets generated internally and externally (goodwill is only generated externally). Goodwill is measured in a business combination purchase by the gap between what is paid for the business and its tangible assets. This "asset" is then depreciated or, if its value falls, "impaired". Second, intangibles other than goodwill(e.g. a patent) are treated as assets if they are acquired externally.. Third, for internally-generated intangibles (e.g. internal R&D), spending is split into a research and development phases. While research spending is almost always ruled as being an expense, development is capitalised under restrictive circumstances, e.g. if the firm can demonstrate with a high degree of certainty that such spending will succeed in generating a long-lived asset.

To make things concrete, British American Tobacco reported in 2015 that they had almost £10bn worth of intangible assets (3bn of tangibles). However, most of the increase that year was via purchases of other companies, most importantly the brand name from buying Rothmans. But if they had invested in building trademarks in-house the additions to intangible assets would have been zero. Thus intangibles from company balance sheets are fundamentally "asymmetric" and can be hard to interpret.

A second source of measuring intangible assets are national accounts, which use a mixture of approaches depending on the type of intangible investment. For purchased intangibles, say software, it uses the cost of purchase. For own-account it uses costs, consisting of payments to labour, capital and intermediates, with data on capital payments often hard to obtain and therefore imputed. Furthermore, many intangible assets, are not currently included in national accounts. Official estimates treat as investment only a limited range of intangible assets: R&D, mineral exploration, computer software and databases, and entertainment, literary and artistic originals (SNA 2008/ESA 2010).

3. Trends in productivity dispersion and intangible investment

As noted in the introduction, productivity growth has not only slowed down in most OECD countries in the past two decades, but firms have also diverged in terms of their productivity. In theory, this phenomenon could be driven either by a reallocation of resources to industries with higher levels of productivity dispersion, or by increased dispersion within industries.

Berlingieri et al. (2017[6]) explore panel data at the country-industry level and find that dispersion both in labour productivity as well as in multi-factor productivity (MFP) has significantly increased especially in the first decade of the 21st century. Interestingly, they find that most of the divergence is driven by within-sector productivity differentials across firms, rather than by cross-sectoral differences.

The same pattern of rising productivity dispersion between firms in the same industry is observed on average in the countries analysed in this report: Data in Figure 1 show a notable increase of MFP dispersion within industries in the sample economies both in manufacturing and market services, even if to a different extent. MFP dispersion between the top 10% and the bottom 10% of firms within their respective country-industry surged between 2000 and 2015 and more prominently in non-financial market services (11%) than in manufacturing (8%).

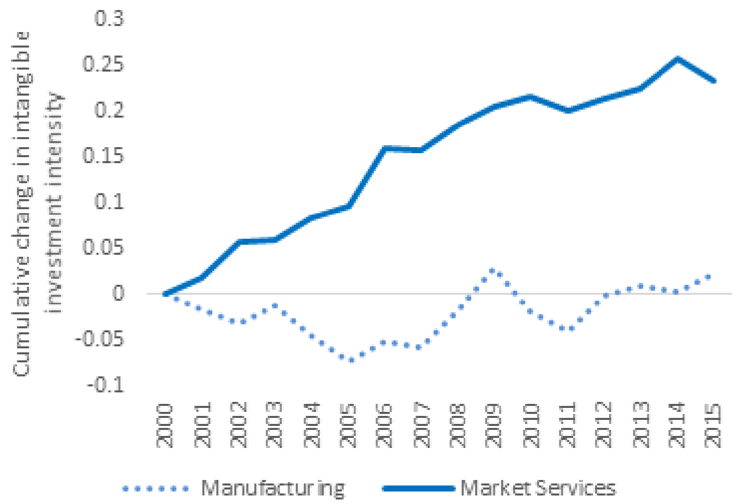
Figure 1. Widening MFP in manufacturing and non-financial market services

Note: The graph plots the evolution of productivity dispersion over time within manufacturing and market services. Unweighted averages across two-digit industries are shown for both groups, normalized to 0 in the starting year. The time period is 2000-15. Productivity dispersion is measured as the 90-10 difference in multi-factor productivity a la Woolridge, i.e. the difference in productivity between firms at the 90th percentile of the productivity distribution in a country-industry and firms at the 10th percentile. The vertical axes represent log-point differences from the starting year: for instance, productivity dispersion in market services has increased by about 0.11 in the final year, which corresponds to approximately 11% higher productivity dispersion in 2015 compared to 2000. Countries included are AUT, BEL, DEU, DNK, FIN, FRA, IRL, ITA, NLD, PRT.
Source: Authors' estimation based on MultiProd database (November 2020).

If the increase in productivity dispersion between firms is indeed partly driven by the rising importance of intangible capital and its crucial role as complementary investment in the digital transition as proposed in the economic literature (Crouzet and Eberly, 2019[15]; Akcigit and Ates, 2019[12]; Haskel and Westlake, 2017[16]; Gutiérrez and Philippon, 2017[17]; Bessen, 2019[39]), the increase in productivity dispersion within industries would be expected to correlate with the industries' evolution of intangible capital.

Therefore, Figure 2 complements Figure 1 showing the evolution of intangible investment intensity (computed as a share of gross output) between 2000 and 2015, both in manufacturing and in non-financial market services. Two important observations arise from this figure: firstly, intangible investment intensity indeed rose over the observation period in both manufacturing and non-financial market services. Secondly, the data suggest that non-financial market services experienced a relatively stronger increase of intangible intensity as opposed to manufacturing. This provides first suggestive evidence for a correlation between productivity dispersion and intangible investment, as the stronger rise in productivity dispersion in non-financial market services is accompanied by a stronger relative increase in intangible investment compared to manufacturing. Figure 3 formalises this observation and shows that increases in intangible intensity tend to be positively correlated to increases in productivity dispersion, each observation in this figure representing an industry in a given country over the period from 2000 to 2007 (left panel) or from 2008 to 2014 (right panel).

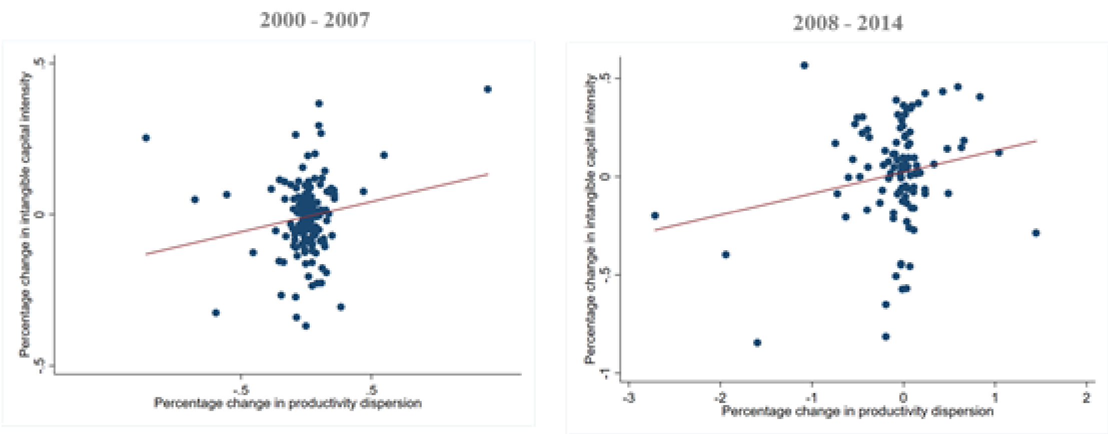
Figure 2. Evolution of intangible intensity



Note: The graph plots the evolution of intangible investment intensity (defined as intangible investment divided by gross value added) for manufacturing and non-financial market services, normalized to the base year 2000. The time period is 2000-15. Countries included are AUT, BEL, DEU, DNK, FIN, FRA, IRL, ITA, NLD, PRT.
Source: Authors' estimations based on MultiProd database (November 2020) and INTAN-Invest database.

Figure 3. Correlations between intangible intensity and productivity dispersion for different time frames

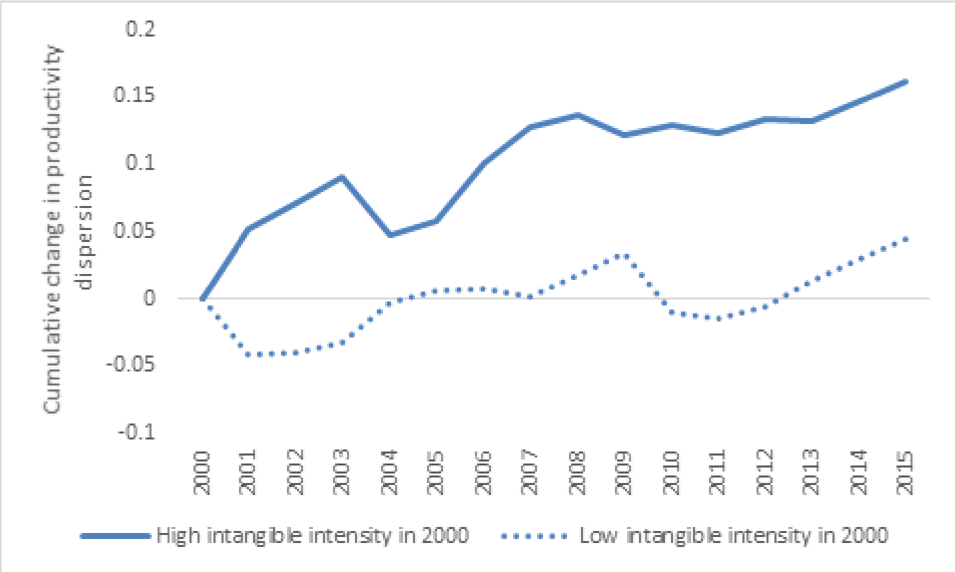
Raw correlations between intangible intensity and productivity dispersion



Note: The graph plots the relationship between the percentage change in productivity dispersion, measured as the 90-10 ratio of MFP within an industry, and the percentage change in intangible capital intensity, measured as ratio between intangible capital and gross value added of an industry, for the periods 2000-2007 and 2008-2014. Each point represents a country-industry pair. Countries included are AUT, BEL, DEU, DNK, FIN, FRA, IRL, ITA, NLD, PRT.
Source: Authors' estimations based on MultiProd database (November 2020) and INTAN-Invest database.

Going one step further, Figure 4 illustrates the link between productivity dispersion within industries and intangible investment after other factors which might explain productivity dispersion – such as tangible capital or labour use of the sector[9] – have been filtered out. In doing so, the figure links intangible investment to the part of productivity dispersion that cannot be explained by other confounding factors. More precisely, the figure shows the cumulative change in productivity dispersion in 2000-2015 for high and low intangible intensive industries. More specifically, the solid (dashed) line refers to the unexplained cumulative change of productivity dispersion for country-industries whose intangible investment intensity is above (below) the median after accounting for difference in average firm size (measured as gross output) and input usage (measured as sectoral average of capital and labour).[10] The figure shows that industries with high intangible intensity experience a steeper rise in otherwise unexplained productivity dispersion over the observation period, which provides further suggestive evidence that intangible investment might be one additional factor contributing to the increase in productivity dispersion. The following sections set out a more rigorous theoretical and empirical framework to investigate this correlation and its potential mechanisms.

Figure 4. Evolution of productivity dispersion by intangible intensity, grouped by intangible intensity in initial year



Note: The graph plots the evolution of productivity dispersion for high and low intangible intensive industries, after controlling for other factors driving productivity dispersion including average gross output, capital and labour inputs and capital-labour ratios. Country-industries are ranked by their intensity of intangible investment in the year 2000. Country-industries above the median are classified as "High intangibles intensity", country-industries below the median as "Low intangibles intensity". Averages weighted by gross output across two-digit industries are shown for both groups, normalized to 0 in the starting year. The time period is 2000-15. Productivity dispersion is measured as the 90-10 difference in multi-factor productivity a la Woolridge, i.e. the difference in productivity between firms at the 90th percentile of the productivity distribution in a country-industry and firms at the 10th percentile. The vertical axes represent log-point differences from the starting year: for instance, productivity dispersion in the high intangible intensity group has increased by about 0.17 in the final year, which corresponds to approximately 17% higher productivity dispersion in 2015 compared to 2000. Countries included are AUT, BEL, DEU, DNK, FIN, FRA, IRL, ITA, NLD, PRT.
Source: Authors' calculations based on MultiProd database (July 2019) and INTAN-Invest database.

4. Theoretical and Empirical Framework

4.1. Theoretical framework

Box 2. The theoretical link between intangibles and productivity dispersion

Recently, theoretical papers, such as Aghion et al. (2019[33]) and De Ridder (2019[34]), develop models which highlight the rise in the importance of intangible capital as a potential mechanism driving the increased productivity dispersion between firms.[11] While both papers provide theoretical models that predict a rise in productivity dispersion as intangible assets become more prevalent in the economy, they have different ways of rationalizing this prediction.

In the setting of De Ridder (2019[34]), the rising importance of intangible capital leads to a change of the cost structure of production, as firms need to invest in the development and maintenance of intangible inputs, which have very high depreciation rates. At the same time, the marginal costs of using these intangibles when production is scaled up are minimal. In his model, firms differ in their efficiency with which they adopt intangible inputs, which more efficient firms can use to undercut their competitors on price, as they can scale up their production and divide their marginal costs over more units of production. This enables them to hold on to market leadership and deter innovation from entrants or even prevent potentially innovative firms from entering the market altogether. In this setting, intangibles would lead to a decrease in productivity growth, reflecting the lower overall level of innovation resulting from leading firms being able to undercut innovative entrants on price. Furthermore, intangibles lead to an increase in productivity dispersion due to increased market power of firms that are efficient at exploiting intangible capital.

Aghion et al. (2019[33]) take a different approach to modelling the impact of intangibles on productivity dispersion. They see especially organisational capital as a source of differences in process efficiency across firms. In their setting, intangible capital is a factor that helps reduce the fixed cost of running multiple product lines (for example, firms like Wal-Mart and Amazon benefit from their established business models and logistics in different geographic markets, or firms like Microsoft and Amazon from their dominant position in cloud storage and computing). As a result, the most efficient firms spread into new markets, while the inability of less efficient firms to imitate leads to them finding their markets more difficult to enter profitably and innovating less. This implies that industries with a higher prevalence of intangible capital among leading firms should experience higher levels of productivity dispersion over time. Contrary to De Ridder (2019[34]) however, productivity growth might increase initially when leading firms expand to new product lines and markets, and only falls later due to a lack of innovation once leaders have pulled away so far that lagging firms lose the ability to imitate.

4.2. Empirical framework

The relationship between intangible investment and productivity dispersion is estimated by means of the following equation:

$$y_{ict}^{90-10} = \beta INTAN_{ict-1}^{agg} + \theta_1 X_{ict}^{avg} + \gamma_{ic} + \gamma_{it} + \varepsilon_{ict} \quad (1)$$

where y_{ict}^{90-10} is the log difference between the 90th and the 10th percentile of the multi-factor productivity a la Woolridge in industry i, country *c* and year *t*. $INTAN_{ict-1}^{agg}$ is per employee intangible investment in industry *i* in country *c* in year *t-1*.

Intangible investment[12] enters the estimation as a lagged term in order to address possible reverse causality between current productivity and intangible investment, as an increase in productivity dispersion might reflect a productivity increase of frontier firms that are more likely to be high intangible intensive. Furthermore, the data on intangible investment varies at the STAN A21 disaggregation level, which makes no distinction between different industries within manufacturing, while the data on productivity dispersion varies at the ISIC revision 4 SNA A38 disaggregation level aggregation level. In order to align the level of variation between the main explanatory and the independent variable, the intangible investment is therefore weighted by the intellectual property products (IPP) investment of an industry within manufacturing as a share of total manufacturing IPP investment in a country in a given year[13]. The rationale of choosing IPP investment as weight is to proxy for the contribution of each industry to intangible investment in manufacturing. Productivity dispersion is likely driven by a multitude of factors, the vector X_{ict}^{avg} includes a set of average control variables: average capital input[14], labour input, gross output, and capital-labour ratio.

The equation also includes country-industry and time fixed effects. The estimated coefficients are identified exploiting the variation within country-A38 industries, meaning that the coefficient of interest β can be interpreted as the correlation between a change in intangible investment within a country-industry and the productivity dispersion within this country-industry. Since country-industry fixed effects sum up to country fixed effects and industry fixed effects, the empirical strategy ensures that the observed correlations are not driven purely by country-specific trends or general characteristics of particular industries. The specification also controls for overall year effects. Equation 1 is estimated with linear regressions. Robust standard errors are clustered for each country-A21 industry pair, reflecting the variation in the intangible measure.[15]

In an extended regression, the relationship between intangible investment and productivity dispersion is estimated as follows:

$$y_{ict}^{90-10} = \beta INTAN_{ict-1}^{agg} + \theta_1 X_{ict}^{avg} + \theta_2 X_{ict}^{90-10} + \gamma_{ic} + \gamma_{it} + \varepsilon_{ict} \quad (2)$$

where X_{ict}^{90-10} is a vector of spread control variables, including the 90-10 differences of capital input, labour input, gross output, and the capital-labour ratio.

5. Findings

5.1. Estimates from the baseline model

This section presents baseline findings on the linkages between intangible investment and productivity dispersion within industries. As seen in Section 3, intangible investment has gained importance over the past two decades, often exceeding the level of tangible investment in several economies (Haskel and Westlake, 2017[16]).

One of the most important differences between intangible and tangible capital is that intangibles are highly scalable, which means that they can be duplicated at very low marginal costs (Haskel and Westlake, 2017[16]).. For instance, new innovation, branding or management practices can be leveraged throughout the organisation, meaning that intangibles can lead to increasing returns to scale and allow intangible-rich leading firms to scale-up. This could contribute to productivity dispersion within industries, due to the higher capacity of large firms to finance the initial sunk cost of intangible investment and then benefit from the gains related to scalability. Additionally, different types of intangibles have been shown to be complementary to each other, with potential for synergies for example between organisational investments and digital intangible assets, such as data or software, but also with (tangible) digital technologies (Bresnahan, Brynjolfsson and Hitt, 2002[52]; Brynjolfsson and Hitt, 2000[53]) which could further strengthen their impact on the productivity distribution within industries.

Indeed, Table 3 shows a significant link between intangible investment and country-industry productivity dispersion. An increase in intangible investment of 10 percentage points, i.e. moving from the bottom (10^{th} percentile) to the median level of intangible investment (or from the median to the top, 90^{th} percentile), is associated to an average 1.8 percentage point increase in dispersion between firms at the 90th and the 10th percentile of the productivity distribution (see columns 1 to 4 of Table 3).

The correlation between intangible investment and productivity dispersion is robust to the inclusion of a wide array of control variables in columns 4 to 6. While average capital input, labour input and gross output are significant drivers of productivity dispersion, they do not affect the general result of a positive link between intangible investment and within-industry productivity dispersion. Furthermore, the results are not sensitive to different time lags of intangible investment. Columns 3 and 6 additionally report the correlation between intangible capital stock and productivity dispersion but on a smaller sample because intangible capital stock is not available for Belgium, Ireland and Portugal. Again, the results are qualitatively robust and of similar magnitude.

Table 3. Regression estimates of equations 1 and 2 (dependent variable: 90-10 difference in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 difference of MFP					
Lagged intangible investment (per employee)	0.178***			0.187***		
	(0.037)			(0.044)		
Contemp. Intangible investment (per employee)		0.165***			0.172***	
		(0.043)			(0.051)	
Contemp. Intangible capital (per employee)			0.184***			0.244***
			(0.058)			(0.055)
Spread controls	NO	NO	NO	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	2,783	3,658	3,658	2,783
R-squared	0.975	0.974	0.966	0.977	0.975	0.969
Num Countries	11	11	8	11	11	8

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital input.

5.2. Results for different categories of intangible investment

Intangibles encompass a broad range of investments that may have differing impacts and policy implications. While the previous sections included total intangible investment in the sector as explanatory variable, this section considers the three subcategories of intangibles as defined in Section 2.3: innovative property (R&D, design…); computer and software; and economic competencies (advertising, marketing, training...). Table 4 shows the baseline estimation results for each of the three components.

Column 1 reports the results for a regression taking innovative property investment as its measure of intangible investment, while column 2 focuses on software and database investment and column 3 reports the results for investment in economic competencies. The estimates show that a ten percentage point higher investment in economic competencies is correlated with about one percentage point higher productivity dispersion. Investment in innovative property and in software and databases on the contrary are not significantly associated with higher productivity dispersion between the 90th and the 10th percentile. While the estimated coefficients for these categories remain positive, they are estimated with much less precision and are significantly smaller in size. Column 4 then estimates a horse race regression, including all three categories of intangible investment at the same time. In this specification, the only intangible category that is significantly correlated to productivity dispersion is economic competencies, with a ten percentage point higher investment in economic competencies is correlated with about 1.8 percentage point higher productivity dispersion once innovative property and software and database investment are controlled for. Columns 5 to 8 replicate the regressions reported in columns 1 to 4, but estimates now control not only for the levels but also the spread of all control variables. The estimates remain virtually unchanged and the relatively stronger importance of economic competencies is confirmed.

Focusing on productivity dispersion at the top of the productivity distribution however shows that innovative property and software and databases also contribute to the correlation between intangibles and productivity dispersion. When using the difference in productivity between firms at the 90th percentile and the median as independent variable in Table 5, the coefficients for innovative property and software and databases remain statistically significant and positive even when controlling for economic competencies. This suggests that these two categories play a role in explaining the correlation between intangibles and dispersion at the top, while there is no correlation between investment in software and databases and innovative property and productivity dispersion at the bottom. However, even at the top of productivity distribution, the main driver of the correlation between intangibles and productivity dispersion remain economic competencies, as the coefficient on this intangible category are the largest in size.

The main take-away from this section so far is that economic competencies emerge as the main drivers of the intangible investment effect on productivity dispersion, especially when looking at the entire productivity distribution.

Therefore, Table 6 further splits the category of economic competencies into its subcategories. Column 1 reports results for a regression where purchased organisational capital investment is used as only measure of intangible investment, column 2 instead focuses on own-account organisational capital investment. Estimates for own account organisational capital investment, reported in column 2, are based on the wages of managerial occupations, and applying capitalisation factors and mark-ups for non-labour costs. The results of these two regressions already suggest a positive and significant correlation between purchased organisational capital investment and productivity dispersion, while own-account organisational capital investment shows no significant correlation. This finding is further supported by column 3, which reports the result of a horserace regression between purchased and own-account organisational capital, again showing only the purchased part of organisational capital investment to be significantly correlated with productivity dispersion (a ten percentage point increase in purchased organisational capital being correlated with an about 1.5 percentage point increase in productivity dispersion). Column 4 additionally adds economic competencies investment that is not organisational capital as well as innovative property and software and databases investment to the regression. The results from this specification show that the purchased component of organisational capital accounts significantly for most of the positive correlation between intangibles and productivity dispersion (a ten percentage point increase in purchased organisational capital being correlated with an about 1.2 percentage point increase in productivity dispersion), contrary to the own-account component. This might lead to potentially downward biased estimates due to imprecisions in the accounting of intangible assets

Box 3. Organisational Capital – What is it and how is it measured?

Organizational capital is a firm-specific capital good jointly produced with output and embodied in the organization itself (Atkeson and Kehoe, 2005[54]; Corrado, Hulten and Sichel, 2005[20]). The asset is viewed as distinct from other forms of knowledge held by a business organization (e.g., its patent portfolio), while also being complementary with other assets and factor inputs, e.g., the well-known complementarity of investments in IT with changes in workplace organization (Bresnahan, Brynjolfsson and Hitt, 2002[52]).

Estimates of organizational capital reflect strategic investments in organizational structure and business processes. Anecdotal examples of structures and processes that enable firms to excel abound, e.g., Wal-Mart's supply chain, Amazon's customer recommendation system. Apple may be famous for its innovation and design, but the way Apple handles inventory also led its success (the company has topped Gartner's Supply Chain Top 25 since 2013).

Estimation Approach

The approach involves estimation of two components, purchases and in-house production. To explain, imagine there is "strategy factory" within a larger organization to which key employees are tasked and charged with creating new, productivity-enhancing processes/practices for the larger organization. Spending on the strategy factory is the organization's investment in organizational capital. The spending includes payments to the employees tasked to the factory (in-house production), as well as payments to outsiders (e.g., McKinsey) that assist in carrying out the factory's charge (purchases).

Estimation Method

The purchased component of investment in organizational capital is assumed to be captured by management consulting services. The in-house component is assumed to be captured by the value of executive managers' time on strategic development of new business practices. Time series for the purchased component are developed from supply-use tables (i.e., purchases of the product, management consulting services, are used). The in-house component is estimated to be a proportion of managers' compensation (the proportionate factor is 0.2). The time series for compensation is developed from available survey data on professional managers' employment and wages.

The above describes methods used to develop the INTAN-Invest industry-level estimates for market sector industries (for further details, see the appendix in Corrado, Haskel, Iommi, and Jona-Lasinio, 2016). For the European countries included in the analysis in this paper, estimates of investment in organizational capital account for 22.5% of total market sector intangible investment, suggesting that organizational investments loom large in the empirics and analysis of intangible capital.

Evaluation

How reliable are these estimates? The proportionate rate applied to managerial compensation is aligned with estimates of managers' marginal revenue product derived from a study based on linked employer-employee data (Piekkola, 2016[55]). A recent survey of manager time-use studies (Martin, 2019[56]) also finds support for the methods used to estimate the in-house component of organizational capital.

Among alternative approaches, a line of work uses "overhead" expenses in corporate financial reports (i.e., SG&A) to estimate organizational capital and finds measured organizational capital to be large and growth enhancing (Lev and Radhakrishnan, 2005[57]). Recent work using this approach reports a high correlation between its estimates of organizational capital and independent information on executive compensation for comparable firms (Eisfeldt and Papanikolaou, 2014[42]). On the other hand, studies using a task-based approach to identify employees for estimating organizational capital found relatively small aggregate estimates, but also substantial heterogeneity across organizations by size and ownership type that may explain divergent results (Le Mouel and Squicciarini, 2015[58]). Still another approach aims to develop methods that better account for the internationalization of intangibles by using firm level information on input-output relationships and global value chains to quantify the value of a firm's organizational capital (the MICROPROD EU project).

Table 4. Regression estimates of equations 1 and 2, splitting different categories of intangible investment (dependent variable: 90-10 difference in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	90-10 difference of MFP							
Lagged innovative property investment (per employee)	0.040*			-0.007	0.060***			0.022
	(0.023)			(0.018)	(0.022)			(0.025)
Lagged software and database investment (per employee)		0.061***		0.015		0.080**		0.000
		(0.022)		(0.016)		(0.031)		(0.021)
Lagged economic competencies investment (per employee)			0.185***	0.175***			0.182***	0.163***
			(0.039)	(0.041)			(0.046)	(0.055)
Spread controls	NO	NO	NO	NO	YES	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.979	0.978	0.979	0.980	0.973	0.973	0.974	0.974
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. “Spread” control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, “average” control variables are the averages of these variables.

Table 5. Regression estimates of equations 1 and 2, splitting different categories of intangible investment (dependent variable: 90-50 difference in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	90-50 difference of MFP							
Lagged innovative property investment (per employee)	0.024*			0.019*	0.037***			0.016**
	(0.014)			(0.011)	(0.013)			(0.007)
Lagged software and database investment (per employee)		0.034**		0.011*		0.046**		0.012**
		(0.016)		(0.006)		(0.025)		(0.007)
Lagged economic competencies investment (per employee)			0.088***	0.080***			0.079***	0.074***
			(0.023)	(0.025)			(0.026)	(0.028)
Spread controls	NO	NO	NO	NO	YES	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.971	0.963	0.965	0.974	0.961	0.962	0.968	0.970
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables.

Table 6. Regression estimates of equations 1 and 2, splitting purchased and own-account organisational capital (dependent variable: 90-10 difference in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	90-10 difference of MFP							
Lagged purchased organisational capital investment (per employee)	0.142***		0.149***	0.126***	0.128***		0.121***	0.105**
	(0.031)		(0.033)	(0.036)	(0.035)		(0.037)	(0.045)
Lagged own-account organisational capital investment (per employee)		0.022	-0.047	-0.049		0.069	0.039	0.031
		(0.044)	(0.043)	(0.044)		(0.051)	(0.047)	(0.048)
Lagged economic competencies investment, excluding organisational capital (per employee)				0.062				0.050
				(0.051)				(0.074)
Lagged innovative property investment (per employee)				-0.012				0.004
				(0.017)				(0.025)
Lagged software and database investment (per employee)				0.016				-0.008
				(0.016)				(0.021)
Spread controls	NO	NO	NO	NO	YES	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.979	0.978	0.979	0.980	0.973	0.973	0.974	0.974
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables.

5.3. Comparison of results for the top and at the bottom of the productivity distribution

The previous sections have analysed the correlation between intangible intensity and productivity dispersion within industries as measured by the difference in productivity of firms at the 90th percentile from those at the 10th percentile. While this measure allows to analyse the evolution of overall dispersion within an industry, it does not allow us to distinguish whether dispersion increased predominantly due to leading firms pulling away from the rest of the industry, or whether dispersion was caused by laggard firms at the bottom of the productivity distribution falling further behind. Distinguishing between these two scenarios is however important for policy. Leading firms pulling away would suggest economies of scale that only the leading firms are able to exploit as well as a problem of knowledge diffusion from the frontier to the majority of firms in an industry, while a scenario of laggard firms falling behind would be more indicative of possible financial constraints that prevent firms that are already relatively unproductive from undertaking intangible investment. In terms of policy design, these two scenarios would call for very different approaches. While the first scenario would call for a better understanding of knowledge diffusion from early adopters and frontier firms to the rest of the industry and for measures that aim at fostering catch-up in an industry, the latter scenario requires focusing on the challenges that laggards face including ways to allow firms at the bottom of the productivity distribution, that are often young and small, to get easier access to financing for intangible investments

This section therefore splits the measure of productivity dispersion into two parts: dispersion at the top (the log difference between the 90th percentile and the median) and the bottom (the log difference between the median and the 10th percentile) of the productivity distribution. If the correlation between intangibles and productivity dispersion is mainly a reflection of greater economies of scale, then most of the dynamics should come from dispersion at the top where (large and more productive) firms benefit disproportionally from economies of scale and can pull away from the rest. If the dynamics is rather driven by laggards not keeping up, the correlation should be stronger between intangible investment and dispersion at the bottom.

Interestingly, the results reported in Table 7 show that the association between intangibles and productivity dispersions at the bottom and at the top are statistically the same (estimates reported in column 2 and column 3). This would be consistent with the link between intangibles and productivity dispersion reflecting both superstar firms pulling away from the median firm and laggards not keeping up with the median firm. To better understand the mechanisms underlying this result, column 2 and column 3 of Table 8 report separately the correlation between intangible investment and productivity growth of frontier and laggard firms, respectively: intangible investment is significantly and positively correlated with the productivity growth of frontier firms, while no significant correlation exists for firms at the 10th percentile of the distribution (which however is predominantly driven by the lower point estimate, while the standard errors are of comparable magnitude). More precisely, the coefficient implies that a ten percentage point increase in intangible investment is associated with about a 1.6 percentage point increase in productivity for firms at the 90th percentile. The absence of a correlation between intangible investment and productivity of laggard firms suggests that laggard firms are either not able to undertake significant amounts of intangible investment, or that they are not able to reap the benefits of intangible investment. This could be due to the impossibility of firms to undertake complementary intangible investments as a bundle, or that they cannot leverage the investment by upscaling. Both in turn could be a reflection of challenges for these firms to access the necessary credit to make those additional investments or for expanding their size.

Table 9 further investigates the drivers of productivity dispersion at the top. As shown in Section 2, the increase in intangible investment intensity over the period from 2000 to 2015 was much more pronounced in market services than in manufacturing. Table 9 therefore estimates equation 1 both for the full sample (column 1) as well as for manufacturing (column 2) and non-financial market services (column 3) separately, focusing on productivity dispersion at the top as outcome variable. As previously, columns 4 to 6 repeat the analysis while adding the 90-10 spreads of all control variables to the estimations. The results show the correlation between productivity dispersion and intangible investment to be larger in size and statistically more significant in market services than in manufacturing, with a ten percentage point increase in intangible investment being associated to a 1.2 percentage point increase in productivity dispersion in manufacturing (column 2), while the same increase in intangible investment in services is correlated with about a 1.6 percentage point increase in non-financial market services. This is in line with the idea that services can scale at a lower cost and with other results in the literature that find higher markups for services than for manufacturing (Andrews, Gal and Witheridge, 2018[59]; Bajgar et al., 2019[60]; Christopoulou and Vermeulen, 2012[61]), and higher productivity dispersion (Berlingieri, Blanchenay and Criscuolo, 2017[6]; Berlingieri et al., 2020[7]).

Table 7. Regression estimates of equations 1 and 2 (dependent variables: 90-10, 90-50 and 50-10 differences in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff.	90-50 diff.	50-10 diff.	90-10 diff.	90-50 diff.	50-10 diff.
Lagged intangible investment (per employee)	0.151***	0.073***	0.079***	0.159***	0.076***	0.083**
	(0.038)	(0.017)	(0.028)	(0.038)	(0.020)	(0.037)
Spread controls	NO	NO	NO	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.979	0.963	0.969	0.974	0.957	0.946
Num Countries	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. “Spread” control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, “average” control variables are the averages of these variables.

Table 8. Regression estimates of equations 1 and 2 (dependent variables: 90-10 difference in MPF_W, MFP_W at 90th percentile, MFP_W at 10th percentile)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff.	p90	p10	90-10 diff.	p90	p10
Lagged intangible investment (per employee)	0.151***	0.162**	0.011	0.159***	0.164*	0.003
	(0.038)	(0.080)	(0.081)	(0.038)	(0.092)	(0.084)
Spread controls	NO	NO	NO	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	3,659	3,660	3,661	3,662	3,663
R-squared	0.979	0.976	0.976	0.979	0.976	0.976
Num Countries	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. “Spread” control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, “average” control variables are the averages of these variables.

Table 9. Regression estimates of equations 1 and 2 for different macro sectors (dependent variable: 90-10 difference in MPF_W)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff. in MFP_W					
Macro sector	All	Manuf.	Services	All	Manuf.	Services
Lagged intangible investment (per employee)	0.178***	0.121***	0.160***	0.187***	0.105*	0.155***
	(0.037)	(0.039)	(0.051)	(0.044)	(0.060)	(0.045)
Spread controls	NO	NO	NO	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	1,702	1,265	3,658	1,702	1,265
R-squared	0.983	0.962	0.974	0.985	0.965	0.967
Num Countries	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables.

5.4. Correlations between intangible capital and firm size

The following subsections report results where intangible investment is interacted with several structural characteristics that might affect the correlation between intangibles and productivity dispersion. The empirical model then reads as follows:

$$y_{ict}^{90-10} = \beta_1 INTAN_{ict-1}^{avg} + \beta_2 (INTAN_{ict-1}^{avg} \times Z_{ic}) \\ \theta_1 X_{ict}^{avg} + \theta_2 X_{ict}^{90-10} + \quad + \gamma_{ic} + \gamma_{it} + \varepsilon_{ict} \tag{3}$$

where Z_{ic} represents different interaction variables such as: (i) the spread of firms size in the sector, proxied by the 90-10 difference in gross output coming from MultiProd, (ii) the digital intensity of the sector, based on the digital intensity taxonomy developed in Calvino et al. (2018), (iii) trade openness, (iv) product market regulation from the OECD PMR Indicators and Database, (v) tax and direct support for R&D from the OECD R&D Tax Incentive Database and (vi) last but not least, credit to non-financial corporations as collected by the BIS.

Up to now the analysis has shown a robust link between intangible investment and within-industry productivity dispersion both through leading firms pulling away from the median firm and laggard firms falling further behind the median, the report now takes a closer look at one potential explanation for the dynamics at the top of the productivity distribution: the potential for economies of scale through intangible investment.

One of the key arguments to assume intangible investment to be correlated with higher productivity dispersion is the potential for scalability of intangible assets. Recent empirical contributions such as Lashkari, Bauer and Boussard (2018[37]) and McKinsey (2018[38]) show that the most profitable firms invest larger shares of their revenues in intangible capital. Bessen (2019[39]) further highlights the scalability of intangibles as an advantage for firms that are already large. The key argument for this idea comes from the relatively low marginal cost of intangible capital, that can easily be used repeatedly and in multiple places at the same time, contrary to tangible assets. This puts large firms in a position where the initial cost of intangible investment can be leveraged over larger quantities of production with little to no additional cost, while smaller firms would have to incur the same cost of investment even if their production is much lower.

In the empirical framework of this paper, another argument to suspect the correlation of intangible investment and productivity dispersion to be linked to differences in firm size is based on the way intangibles are measured at the industry level, while productivity is measured at different quantiles of productivity within an industry. Since intangibles are both unaccounted for in the productivity estimates coming from the MultiProd database, a concentration of intangibles in large firms would contribute to measured productivity dispersion if large firms also tend to be the most productive firms. In this scenario, where intangibles are an uncounted factor of production in firms at the 90th productivity percentile but not in firms at the 10th percentile, a rationale for a correlation between intangibles and productivity dispersion would be misstated MFP via omission of a growing factor of production.

One way to test whether intangible investment correlates with productivity dispersion through differences in firms size is to test whether the correlation is stronger in industries that are characterised by large disparities in firm size. Table 10 conducts this test by interacting intangible investment with a dummy variable that takes the value of 1 if the 90-10 difference in gross output in a country-industry-year is higher than the sample median as measure of size dispersion. A positive coefficient on the interaction term between intangibles and size dispersion would signify that intangibles increase dispersion particularly in industries with large disparities in firm size.

Columns 1 and 2 report the results for regressions where intangible investment is interacted with the dispersion in terms of gross output within an industry (first using only average control variables in column 1, then adding spread control variables in column 2) in manufacturing, while columns 5 and 6 repeat the same exercises for non-financial market services. Columns 3 and 4 show results for regressions interacting intangible investment with within-industry dispersion in terms of labour input in manufacturing, columns 7 and 8 show results for non-financial market services.

Two main findings emerge from this exercise: firstly, when focusing on the manufacturing sector, it becomes evident that the link between intangible investment and productivity dispersion in manufacturing is closely related to firm size, as both the interaction term with size dispersion measured by the industry spread in gross output (columns 1 and 2) and the interaction term with size dispersion measured by the industry spread in labour input are significantly positive (columns 3 and 4). Secondly, when looking at non-financial market services, the size interaction is only significant when size is measured by labour input (columns 7 and 8), but not for the interaction with gross output dispersion (columns 5 and 6). Table 11 zooms in on this finding and additionally splits the services sample according to their skill intensity. Columns 1 to 4 present the results of sub-sample analysis of low skill intensity service industries, columns 5 to 8 focus on skill intensive non-financial market services. This reveals that in skill intensive services, there are no significant complementarities between intangible investment and firm size (insignificant interaction terms in all columns 5 to 8), while in industries with low skill intensity, intangibles are to labour input (columns 2 and 4). Furthermore, in industries with low skill intensity, the result of columns 1 and 3 provide evidence for a significant interaction between firm size as measured by gross output and intangible investment.

Table 10. Regression estimates of equation 3 (dependent variable: 90-10 difference in MPF_W, interaction variable: size dispersion measured by 90-10 difference in gross output)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Macrosector		Manufacturing				Market Services		
Dependent Variable								
Lagged intangible investment (per employee)	-0.016	0.044	-0.021	0.043	0.116*	0.104**	0.027	0.010
	(0.058)	(0.089)	(0.061)	(0.102)	(0.058)	(0.040)	(0.048)	(0.033)
x Dummy for high GO dispersion	0.151**	0.168**			-0.038	0.012		
	(0.064)	(0.043)			(0.093)	(0.073)		
x Dummy for high L dispersion			0.142*	0.170**			0.167*	0.233***
			(0.070)	(0.065)			(0.086)	(0.059)
Spread controls	NO	YES	NO	YES	NO	YES	NO	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,702	1,702	1,702	1,702	1,265	1,265	1,265	1,265
R-squared	0.963	0.959	0.962	0.959	0.977	0.950	0.978	0.953
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables. The dummy for high size dispersion takes the value 1 if the 90-10 difference in gross output in a country-industry-year is higher than the sample median.

Table 11. Regression estimates of equation 3 (dependent variable: 90-10 difference in MPF_W, interaction variable: size dispersion measured by 90-10 difference in gross output)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Macrosector	Non-Financial Market Services							
Dependent Variable	90-10 difference of MFP							
Skill intensity	Low intensity				High intensity			
Lagged intangible investment (per employee)	0.193**	0.212***	0.229***	0.220**	0.096	0.081	0.139*	0.140**
	(0.074)	(0.066)	(0.071)	(0.081)	(0.066)	(0.068)	(0.071)	(0.067)
x Dummy for high gross output dispersion	0.202		0.337*		-0.127		-0.060	
	(0.149)		(0.187)		(0.077)		(0.070)	
x Dummy for high labour dispersion		0.151		0.440**		-0.069		-0.066
		(0.151)		(0.210)		(0.074)		(0.070)
Spread controls	NO	NO	YES	YES	NO	NO	YES	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,265	1,265	1,265	1,265	1,265	1,265	1,265	1,265
R-squared	0.975	0.982	0.960	0.977	0.975	0.982	0.960	0.977
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables. The dummy for high size dispersion takes the value 1 if the 90-10 difference in gross output in a country-industry-year is higher than the sample median.

5.5. Complementarities with digital technologies

This section empirically tests the potential complementarities between intangible investment and digital technologies. The transition to a digitalised economy has been linked to a reinforced need for good management and training of workers, as well as appropriate skills and ICT intangible assets to complement ICT tangible investment (Berlingieri et al., 2020[7]). For instance, investment in hardware yields its full benefits only to firms that also invest in software and the training of workers. These potential synergies between intangible assets and digital technologies show that intangible assets can be a driving force of productivity growth, but can also harm the diffusion process a benefitting from digital technologies may require significant complementary investments, which might be too costly to undertake for smaller and less productive firms.[16]

In order to measure digital intensity at the industry level, this report draws on the work of Calvino et al. (2018[62]), which proposes a taxonomy that benchmarks industries by their degree of digital intensity. This taxonomy combines several indicators capturing different technological components of digital intensity (tangible and intangible ICT investment, purchases of intermediate ICT goods and services, robots), the human capital it requires to embed technology in production (ICT specialists intensity and ICT task intensity), and the way digital technologies change the interface of firms with the output market (online sales). On the basis of these indicators, a unified ranking of ICT intensity across 36 ISIC revision 4 sectors between 2001 and 2015 is created, allowing for cross-industry comparisons of digital intensity.

Table 12 presents estimates of equation (3) with an interaction between intangible investment and the digital intensity of a sector. Columns 5 and 6 of Table 12 show that digital intensity and intangible investment indeed act as complements when productivity dispersion between firms at the bottom of the distribution and the median firm is considered, with sectors with lower digital intensities (i.e. higher ranks) experiencing significantly lower increases in productivity dispersion at the bottom when intangible investment is increased. This suggests that, within digital intensive sectors, intangible investment contributes to a lack of diffusion of technologies to laggard firms.

One drawback of the analysis in Table 12 is the potential correlation between the intangible investment measure and the digital intensity indicators, as some sub-indicators used in the digital intensity taxonomy (i.e. software and databases) are also included in the intangible investment measures, thus potentially causing double counting. Table 13 addresses this issue and takes as a measure of digital intensity only the investment in hardware. The results remain qualitatively the same, with the coefficients of interest being slightly smaller in size. Most importantly, the first row of columns 5 and 6 confirms that the baseline correlation between intangibles and productivity dispersion between the median firm and the firm at the 10th percentile is statistically insignificant in industries that are not digital intensive. The positive and statistically significant interaction term between the dummy for high digital intensity and intangible investment in columns 5 and 6 shows that within digital intensive industries, intangible investment is positively correlated with productivity dispersion at the bottom.

This finding suggests that intangibles are associated to higher productivity dispersion between the least productive firms and the rest of the firms predominantly through their complementarity with digital technologies, as the estimated coefficients are only significant for relatively digital intensive industries. As digital technologies necessitate intangible investment, laggard firms which are unable to carry out the necessary intangible investment fall behind in digital intensive sectors. Conversely, the link between intangibles and dispersion between frontier firms and the median does not depend on digital intensity and seems to be driven by other factors. These findings provide one potential explanation for the results in Berlingieri et al. (2020[7]), who find that laggard firms catch-up to the productivity frontier at a lower speed in more digital intensive and more knowledge intensive industries. The slower diffusion of knowledge from frontier firms to laggards that drives productivity divergence in digital intensive industries can be explained by the need for intangible investment as a complementary input to digital technologies, which represents an additional obstacle for laggards.

Table 12. Regression estimates of equation 3 (dependent variable: 90-10, 90-50 and 50-10 differences in MPF_W, interaction variable: digital intensity)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff. MFP		90-50 diff. MFP		50-10 diff. MFP	
Lagged intangible investment (per employee)	0.076	0.119**	0.054*	0.080**	0.022	0.039
	(0.048)	(0.049)	(0.029)	(0.038)	(0.029)	(0.032)
x High initial digital intensity	0.168**	0.100	0.043	-0.017	0.125***	0.117**
	(0.075)	(0.091)	(0.047)	(0.065)	(0.047)	(0.056)
Spread controls	NO	YES	NO	YES	NO	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.979	0.972	0.963	0.959	0.977	0.950
Num Countries	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables. The dummy for high digital intensity takes the value 1 if the cross-indicator rank as described in Calvino et al. (2018) is higher than the sample median.

Table 13. Regression estimates of equation 3 (dependent variable: 90-10, 90-50 and 50-10 differences in MPF_W, interaction variable: digital intensity)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff. MFP		90-50 diff. MFP		50-10 diff. MFP	
Lagged intangible investment (per employee)	0.124**	0.138**	0.079**	0.095**	0.045	0.043
	(0.060)	(0.068)	(0.038)	(0.047)	(0.038)	(0.035)
x High initial digital intensity (hardware only)	0.049	0.039	-0.023	-0.040	0.072**	0.079**
	(0.039)	(0.042)	(0.034)	(0.042)	(0.034)	(0.039)
Spread controls	NO	YES	NO	YES	NO	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.976	0.968	0.961	0.957	0.971	0.945
Num Countries	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables. The dummy for high digital intensity takes the value 1 if the cross-indicator rank as described in Calvino et al. (2018) is higher than the sample median.

5.6. Importance of product market regulation and trade for the link between intangible investments and productivity dispersion

Table 14 interacts intangible investment with trade openness and finds evidence that the correlation between intangible investment and productivity dispersion is stronger in country-industries that are more open to international trade. This suggests that trade liberalisation might be more inclusive and lifts the whole productivity distribution up if it was accompanied by measures that facilitate the investment in necessary intangible assets. Columns 1 and 2 present results for regressions including an interaction term between intangible investment and a dummy taking the value 1 if the trade openness of a country in the initial year 2000 was above the sample median. The results show that while intangible investment is correlated with higher productivity dispersion even in countries with low initial trade openness, the correlation becomes significantly stronger in countries that were initially more open to international trade.

Furthermore, the table presents results for interaction between intangibles and product market regulation in columns 3 and 4, which are statistically insignificant both when control variables are used in levels as well as when both levels and spreads of control variables are used.

Table 14. Regression estimates of equation 3 (dependent variable: 90-10 difference in MPF_W, interaction variables: trade openness and product market regulation)

	(1)	(2)	(3)	(4)
Dependent Variable	90-10 diff. MFP			
Lagged intangible investment (per employee)	0.106***	0.143***	0.153***	0.169***
	(0.036)	(0.029)	(0.040)	(0.038)
x High initial trade openness	0.209**	0.172*		
	(0.086)	(0.101)		
x High initial product market regulation			-0.318	-0.315
			(0.222)	(0.215)
Spread controls	NO	YES	NO	YES
Average controls	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658
R-squared	0.979	0.972	0.979	0.972
Num Countries	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. “Spread” control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, “average” control variables are the averages of these variables. The dummy variable for high initial trade openness (product market regulation) takes the value 1 if the initial trade openness (product market regulation) of a country-industry-year.

5.7. Complementarities with venture capital and R&D financing

As seen in previous sections, intangible investment is linked to higher productivity dispersion at least in part because young and low productivity firms do not undertake the necessary intangible investment to grow. As young firms are particularly exposed to face financing constraints, Table 15 analyses the role of start-up and early stage venture capital in the link between productivity dispersion and intangible investment. Data on venture capital comes from the OECD Entrepreneurship at a Glance database.

The estimates provide evidence that early stage venture capital investment is linked to lower productivity dispersion, even if slightly less so in intangible intensive sectors. A split into dispersion at the bottom and the top already provides a better understanding of the underlying mechanisms and of where the dynamics take place, i.e. amongst young firms that have to grow the productivity ladder. While the link between intangible investment and productivity dispersion at the top is not affected by venture capital availability, productivity dispersion at the bottom is significantly lower when venture capital is higher even in intangible intensive sectors. This finding suggests that intangible investment has a differentiated impact on productivity dispersion depending on venture capital. In Table 15, the positive sign of the interaction between intangible intensity and venture capital (columns 5 and 6) indicates that venture capital exerts a mediating effect in the relationship between intangible investment and productivity dispersion. One possible explanation might be that venture capital partly mitigates the impact of intangibles on productivity dispersion facilitating knowledge diffusion via knowledge spillovers from venture capital backed firms. More specifically, venture capital might act as a complementary factor to intangibles favouring knowledge transfer mainly among laggards and youngest firms.[17]

Table 16 adds further evidence for a potential alleviating effect of R&D financing on the correlation between intangibles and productivity dispersion. Columns 1 to 4 present results for regressions where intangible investment is interacted with the B-index, a measure of the pre-tax income needed for a company to break even on a marginal, monetary unit of R&D outlay. The index takes into account tax relief provisions to derive implied tax subsidy rates (1 minus the B-index) and reflects the implications of investing an additional monetary unit in R&D. In countries with higher implied tax subsidy rates, link between intangibles and productivity dispersion is weaker (negative coefficients on all interaction terms in columns 1 to 4). The same holds for columns 5 to 8, where intangibles are interacted with the mean deviation of credit to firms from a long run trend (positive deviations implying easier access to credit), suggesting that laggard firms might face financial frictions which might hinder the necessary complementary investment in intangibles and therefore their ability to adopt new technologies. This is underlined by the fact that columns (3), (4), (7) and (8) of Table 16 show that the facilitation of R&D financing especially the correlation between intangible investment and productivity dispersion at the bottom of the distribution becomes weaker in industries with easy access to credit or high levels of tax subsidies.

Table 15. Regression estimates of equation 3 (dependent variable: 90-10, 90-50 and 50-10 differences in MPF_W, interaction variable: venture capital investment)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	90-10 diff. MFP		90-50 diff. MFP		50-10 diff. MFP	
Lagged intangible investment (per employee)	0.035	0.031	0.017	0.016	0.018	0.015
	(0.028)	(0.026)	(0.028)	(0.030)	(0.014)	(0.013)
Start-up and other early stage VC, %GDP	-0.155***		-0.023		-0.132***	
	(0.036)		(0.018)		(0.029)	
x Lagged intangible investment	0.020***		0.002		0.018***	
	(0.007)		(0.006)		(0.005)	
Venture capital investments, Total, %GDP		-0.027		0.005		-0.032*
		(0.033)		(0.006)		(0.019)
x Lagged intangible investment		0.002		-0.001		0.003*
		(0.006)		(0.006)		(0.006)
Spread controls	YES	YES	YES	YES	YES	YES
Average controls	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES
Observations	1,771	1,771	1,771	1,771	1,771	1,771
R-squared	0.964	0.956	0.960	0.954	0.969	0.960
Number of Countries	10	10	10	10	10	10

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. "Spread" control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, "average" control variables are the averages of these variables.

Table 16. Regression estimates of equation 3 (dependent variable: 90-10, 90-50 and 50-10 differences in MPF_W, interaction variables: access to credit and tax subsidies)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	90-10 diff. MFP		50-10 diff. MFP		90-10 diff. MFP		50-10 diff. MFP	
Lagged intangible investment (per employee)	0.162***	0.156***	0.072**	0.156***	0.156***	0.262***	0.072**	0.156***
	(0.043)	(0.045)	(0.030)	(0.047)	(0.045)	(0.061)	(0.030)	(0.047)
x Mean B-index	-0.013***	-0.008***	-0.012***	-0.015**				
	(0.003)	(0.002)	(0.003)	(0.007)				
x Mean deviation of credit to firms					-0.010	-0.014**	-0.011***	-0.009**
					(0.008)	(0.006)	(0.003)	(0.004)
Spread controls	NO	YES	NO	YES	NO	YES	NO	YES
Average controls	YES	YES	YES	YES	YES	YES	YES	YES
Country x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Year x Industry A38 FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,658	3,658	3,658	3,658	3,658	3,658	3,658	3,658
R-squared	0.979	0.972	0.970	0.943	0.979	0.972	0.969	0.943
Num Countries	11	11	11	11	11	11	11	11

Note: Regressions at the country-A38 industry level. Robust standard errors are clustered at the country–A21 industry level in parentheses. ***, **, * represent significance at the 1%, 5% and 10% level respectively. All variables are in natural logarithms, with the exception of the share of hours worked by high-skilled workers. “Spread” control variables are the 90-10 differences of labour input, capital input, gross output and the capital labour ratio, “average” control variables are the averages of these variables.

6. Policy Considerations and Conclusions

The results in this report suggest a significant link between intangible investment and productivity dispersion at the industry level. Industries with higher levels of intangible investment on average experienced higher increases in productivity dispersion between firms. On average, an increase in intangible investment of 10 percentage points on average is associated to a approximately 1.5 percentage point increase in dispersion between firms at the 90th and the 10th percentile of the productivity distribution. This baseline result is predominantly driven by the market services sector, while the link between intangible investment and productivity dispersion is much weaker in manufacturing on average.

The report furthermore provides evidence that intangibles are associated with higher productivity dispersion both at the top and at the bottom of the productivity distribution. The dispersion between firms at the 90th percentile and the median is linked to intangible investment particularly in industries with larger dispersion of gross output and firm size.

While on average, the link between intangible investment and productivity dispersion is predominantly driven by the market services sector and less prevalent in manufacturing, the size effects of intangible investment are much stronger in manufacturing. In manufacturing, intangible investment is associated with significant increases in productivity dispersion in country-industries that are characterised by larger differences between firms in terms of output and firm size. In services however, intangible investment is only associated to gross output and firm size in industries with low skill intensity.

Intangible capital is also found to be a key factor ensuring the inclusiveness and the success of the digital transformation. The empirical results suggest that intangibles are associated to higher productivity dispersion between the least productive firms and the rest of the firms predominantly through their complementarity with digital technologies. As digital technologies necessitate intangible investment, laggard firms which are unable to carry out the necessary intangible investment fall behind in digital intensive sectors. The slower diffusion of knowledge from frontier firms to laggards that drives productivity divergence in digital intensive industries can be explained by the need for intangible investment as a complementary input to digital technologies, which represents an additional obstacle for laggards.

Finally, the analysis on the importance of financing point to venture capital as one type of financing that seems particularly important, as the provision of funds by development stage reduces uncertainty for investors. Especially in digital intensive industries, the lack of intangible investment by laggard firms acts as an impediment to productivity catch-up of these firms. As empirical research has shown that firms under financial constraints give preference to pledgeable assets (Planes-Satorra and Paunov, 2019[63]), one way to address the lack of intangible investment by laggard firms could be to improve the pledgeability of intangible capital. IP backed loans have already been implemented in several countries and shown encouraging results (Demmou, Franco and Stefanescu, 2020[47]). Another way to increase investment of start-ups and SMEs in intangible assets is tailored government support, such as a fund to support start-up liquidity in France, a tailored start-up aid programme in Germany, or a co-financing fund for innovative companies facing financial difficulties in the United Kingdom (OECD, 2020[11]). With regards to the regulatory framework, competition policy can create incentives to improve management and efficiency thus increasing investment in organisational capital, and IPR legislation has been shown to be able to play a role in stimulating intangible investment (Guo-Fitoussi, Bounfour and Rekik, 2019[64]).

Furthermore, the results concerning trade openness suggest that policies of trade liberalisation should ideally be accompanied by measures to increase to ability of laggard firms to undertake intangible investment.

Endnotes

[1] A long standing literature has shown that R&D plays a decisive role in determining differences in productivity across firms and firm level productivity growth (see Hall, Mairesse and Mohnen, 2010, for an extensive for a literature review and the work cited in Syverson, 2011).

[2] MultiProd, DynEmp, and MicroBeRD are projects carried forward by the Directorate for Science, Technology and Innovation (STI) at the OECD. The DynEmp (Dynamics of Employment) project provides harmonised micro-aggregated data to analyse employment dynamics (find out more: http://www.oecd.org/sti/dynemp.htm) and MicroBeRD provides information on R&D activity in firms from official business R&D surveys (find out more: http://www.oecd.org/sti/rd-tax-stats.htm).

[3] Further details about the representativeness of the MultiProd dataset, as well as a comparison with the STAN dataset, can be found in Bajgar et al. (forthcoming).

[4] This is, for example, the case for Italy and the Netherlands.

[5] For details on country and industry coverage, see Desnoyers-James et al. (2019)

[6] The non-financial market service sector includes the following 2-digit sectors: Wholesale and retail trade, repair of motor vehicles and motorcycles; Transportation and storage; Accommodation and food service activities; Publishing, audiovisual and broadcasting activities; Telecommunications; IT and other information services; Legal and accounting activities; Scientific research and development; Advertising and market research, other professional, scientific and technical activities, veterinary activities; Administrative and support service activities.

[7] Note that the capital input in MultiProd excludes intangible capital.

[8] INTAN-Invest also computes intangible capital stocks for most countries. However, this is not the case for Belgium, Ireland and Portugal.

[9] For the construction of the figure, control variables are only used as averages. Section 5 shows empirical results both for specifications where control variables are used only in averages as well as specifications combining averages and 90-10 ratios of all controls.

[10] The graph plots the residual of the following empirical model separately for low intangible intensity and high intangible intensity industries: $y_{ict}^{90-10} = \theta_1 X_{ict}^{avg} + \gamma_{ic} + \gamma_{it} + \varepsilon_{ict}$, where y_{ict}^{90-10} is the 90-10 difference in MFP in industry i in country c in year t, X_{ict}^{avg} is a vector containing the control variables average gross output, average capital input and average labour input, and average capital intensity, and γ_{ic} and γ_{it} are country-industry and country-year fixed effects.

[11] For future versions of this report, a theoretical model is currently being developed.

[12] The inclusion of investment among the explanatory variables relies on the assumption that as intangible assets are characterized by fast depreciation rates, investment is a reasonable approximation of changes in capital stocks (see for instance Corrado et al., 2012). Furthermore, data on intangible capital stocks is not available for Belgium, Ireland and Portugal, which is another motivation for choosing investment as explanatory variable.

[13] Data on IPP is taken from Eurostat. For country-industry-years where no IPP data is available, the cross-country average share in the respective year is applied.

[14] While this measure should in principle capture tangible capital in MultiProd, some countries also include some information on intangible capital (mainly software and R&D investments).

[15] Note that as anticipated in the Data section (Sections 2.1. and 2.3) MultiProd is available at A38 while INTAN-Invest is at A21 (for details see Table A1 in the Appendix).

[16] Andrews et al. (2015) and Andrews et al. (2016) point out that digital transformation and the transition to an economy based on ideas seem to have intensified the role of capabilities and incentives in technology adoption.

[17] For a review on the role of VC favouring knowledge transfer, see Dessi and Yin (2014[67]).

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