

Roth, Felix; Mitra, Alessio

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EU Competitiveness: The Critical Role of Intangible Assets in EU Labour Productivity Growth

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Felix Roth

Alessio Mitra

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Editor:

PD Dr. Felix Roth

University of Hamburg

Senior Lectureship in International Economics

Von-Melle-Park 5

20146 Hamburg

Postfach #17

Felix.Roth@uni-hamburg.de

Homepage: <https://www.felixroth.net/>

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EU Competitiveness: The Critical Role of Intangible Assets in EU Labour Productivity Growth¹

By Felix Roth* and Alessio Mitra**

* *University of Hamburg, Department of Economics, Von-Melle-Park 5, Postfach #17, 20146 Hamburg, Germany. Email : felix.roth@uni-hamburg.de*

** *European Commission, DG Research and Innovation, ORBN 02/143, 1000 Brussels, Belgium. Email : alessio.mitra1@ec.europa.eu*

Abstract

The European Union (EU) faces challenges such as an ageing population, migratory pressures, geopolitical vulnerabilities, and climate change, highlighting the need to enhance its ability to do more with less. This paper examines the drivers of EU labour productivity before and after the 2007 financial crisis, across goods and services sectors, tangible and intangible assets, and Information and Communication Technologies (ICT) and non-ICT tangibles. Using the EUKLEMS 2022 dataset for 14 EU countries and the UK from 1995-2019 and growth regression analysis, we find that Research & Innovation (R&I) is crucial for productivity growth. Labour productivity in the goods sector benefits most from non-ICT tangible assets, while in the service sector, it benefits more from the non-R&D intangibles software, training, and organisational capital. On the other hand, training and ICT tangibles became more important drivers of labor productivity growth after the economic crisis. We argue that the productivity gap between the EU and the United States is largely due to insufficient investment in non-R&D intangibles like software, training, and organizational capital.

1. Introduction

In recent years, the European Union (EU) has found itself at a critical juncture for its competitiveness, facing many challenges capable of undermining the EU's prosperity and ambitions. This paper seeks to dissect and understand the multifaceted drivers behind EU labour productivity, which is pivotal for the region's economic competitiveness and sustainability.

The motivation behind this analysis stems from several urgent societal and environmental challenges confronting the EU today, including an ageing population, the pressures on the

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European social model, economic security necessities, and the imperative of climate change. These elements collectively underscore the necessity for the EU to enhance its labour productivity, particularly in the service sector, where there exists a significant untapped potential compared to its transatlantic counterpart, the United States.

The ageing demographic trend within the EU poses a formidable challenge, necessitating that fewer workers sustain the social needs of an increasingly older population. This demographic shift places unprecedented strain on the European social model, known for its comprehensive welfare states, by threatening its fiscal sustainability. Moreover, migratory pressures, fueled by geopolitical unrest and climate-induced natural disasters, further exacerbate these challenges, testing the resilience and adaptability of the EU's social and fiscal structures.

In parallel, geopolitical developments have illuminated the vulnerabilities and dependencies embedded within global supply chains. The resulting economic security and trade dependency concerns may increase in the short run the cost of the green transition, due to supply chain disruptions and reshoring.

At the heart of these intertwined challenges lies the concept of doing more with less, a principle represented by the concept of productivity; the efficiency with which inputs, like resources, are converted into outputs, such as products and services. Productivity growth becomes increasingly relevant if the EU wants to sustain its socio-economic model, produce at reasonable costs, and deploy at scale the necessary green technologies to succeed in the European Green Deal while decoupling economic growth from environmental degradation.

One of the critical areas identified for potential improvement in labour productivity within the EU is the service sector. The productivity gap between the EU and the US can largely be attributed to the EU's insufficient focus on non-R&D intangibles, such as software and organizational capital. These elements are crucial drivers of labour productivity growth in the service sector, representing a significant opportunity for enhancing the EU's economic performance and competitiveness on the global stage.

This paper aims to unravel the complex interplay between these drivers, offering insights into the pathways through which the EU can bolster its labour productivity growth. The paper explores the evolution over time of the contribution of different intangible assets, and tangible towards labour productivity growth across the EU. On the intangible we focus on software, R&D, firm-specific human capital (or vocational training), organisational capital. While on the tangible we differentiate between ICT tangible and non-ICT tangible.

By delving into the challenges and opportunities presented by an ageing population, migratory pressures, geopolitical developments, and the imperatives of climate change, this analysis seeks to contribute to the discourse on sustainable economic development within the EU, with a particular focus on the pivotal role of the service sector.

2. Literature Review

Productivity refers to the efficiency with which we are able to transform input such as resources into output such as products. In essence, greater productivity equips a society with enhanced capabilities to tackle the myriad challenges and uncertainties it encounters. At the same time, productivity is not a solution to all our problems, as political consensus is necessary to direct its fruits toward desirable outcomes (Draghi 2024, EC 2022).

Despite expectations that digital technology would enhance productivity, there has been a noticeable slowdown and stagnation in growth over recent decades. This unexpected outcome has led to extensive research. As Robert Solow pointedly observed in 1987, "You can see the computer age everywhere but in the productivity statistics." Indeed, productivity growth in both the Euro area and the United States has decelerated and stagnated from 1950 to 2022 (EC 2024).

Potential reasons for this include low rates of technological adoption, significant costs for less advanced firms in terms of firm-specific human capital and organisational restructuring, and a decline in business dynamism. Although digital technologies can increase productivity at the individual firm level (Hubbard 2003, Bartel et al. 2007), this does not necessarily scale up to broader economic growth, often hindered by market dynamics and both skills and organisational factors.

Indeed, the effective implementation of information and communication technology (ICT) presents challenges, necessitating additional investments in human capital and alterations in management practices (Pilat 2005; Arvanitis 2004; Maliranta and Rouvinen 2004). Such complementary actions prove particularly burdensome for non-leading-edge firms and can result in negative returns during the transition and experimentation phases (Brynjolfsson et al. 2019). This feature has led to productivity polarisation, with a few leading firms advancing the technological frontier, while many laggard firms struggle to keep pace (Calvino et al. 2018; Berlingieri et al. 2017), and a decline in business dynamics, with 'zombie firms' surviving solely due to public subsidies. These factors have prevented so far digital technology-led productivity growth from transitioning from an individual firm level to a whole-economy factor (EC 2022).

The EU faces a growing productivity gap with the US. Several factors contribute to this disparity. Firstly, the US population is younger, expands more rapidly, and works longer hours. Additionally, when adjusted for purchasing power parity (PPP), the productivity gap narrows slightly.² However, a significant portion of the gap persists because US workers are more productive per hour. This is partly due to the EU being caught in a middle-technology trap (Fuest, C, et al., 2024), where its R&D is predominantly concentrated in mid-tech industries such as automobiles and parts. In contrast, US R&D excels in high-tech sectors like software, computer services, and pharmaceuticals and biotechnology. The EU not only focuses on sectors with generally lower R&D intensity (a structural difference) but also exhibits lower average R&D intensity across most

² See: The Economist, "Productivity has grown faster in western Europe than in America. Long hours and a strong dollar give America the lead in GDP per person", 2023, ([link](#))

sectors (an intrinsic difference) (Draghi 2024, EC 2024). Furthermore, EU patenting activity tends to involve less complex technologies compared to the US (Di Girolamo, V., Mitra, A., Ravet, J. 2023).

One explanation for this middle-technology trap could be differences in how the EU and the US manage their intangible assets. Indeed, as mentioned above, intangibles such as human capital, and organizational capital are among the key drivers of the productivity paradox, explaining digital technology adoption and diffusion in the economy. The concept of intangible capital as a productive input has been recognized since the early 1960s (Haskel and Westlake 2018).

Following the publication of Corrado, C., Hulten, C., and Sichel, D. (2005), there has been a surge in national studies assessing the impact of intangible capital on labour productivity growth. These studies have led to the development of several databases, such as the European Commission-funded FP7 INNODRIVE project, which created a comprehensive intangible capital dataset for EU-27 at the cross-country level. This dataset was further enriched culminating in the first two harmonized EU KLEMS cross-country datasets (O'Mahony and Timmer 2009; Stchrer et al. 2019; Bontadini et al. 2021).

Nevertheless, many cross-country aggregate and sectoral econometric analyses currently present mixed results, wherein the contribution of intangible capital to labour market productivity substantially varies and does not consistently achieve statistical significance. Roth and Thum (2013) assert that intangible capital accounts for 50% of labour productivity growth in the EU12 + UK between 1998 and 2005. Roth (2020) suggests that intangible capital deepening contributes to 46% of labour market growth in the EU15 + UK over the period 2000-2015. Corrado et al. (2016) found that intangible capital deepening explains 25% of labour productivity growth in the EU12 from 1995 to 2010. Conversely, Adarov and Stehrer (2019) observed no significant impact of intangible capital on labour productivity across the EU20, Japan, and the US during the period 2000-2017. Roth (2024) finds that intangible capital deepening accounts for around 40 percent of labor productivity growth at both the aggregate and sectoral levels, with non-R&D intangibles playing a major role in the service sector, and R&D intangible having relevance mostly in the manufacturing sector. The reasoning for such mixed results can be attributed to differences in the research design (incl. country and sectoral case selection and time coverage), methodological approach and usage of datasets. A complete overview of these differences in the existing literature is given in the Roth (2024, 2025).

Furthermore, De Ridder (2024) employs an endogenous growth model to argue that R&D becomes less effective due to the rise of intangible inputs, such as information technology and software, which require higher organisational and human capital to be used effectively. This leads to a productivity divide and the emergence of a few star firms, with R&D concentrated among a small number of these firms. And a portion of innovators are unable to surpass the high-intangible incumbents.

We contribute to the above mentioned literature on the impact of intangible capital on labour productivity growth in a threefold manner. First, by introducing a model specification which distinguishes between non-ICT and ICT capital and targeting the four distinct intangibles: research and development (R&D), software, organisational capital, and firm-specific human capital. Second, by expanding our sample to include the EU14+UK from 1995 to 2019. Third, by distinguishing between a before and after the 2008 economic crisis sample.

3. Model Specification, Data, Research Design

3.1. Model Specification

This paper uses a slightly adapted model specification as developed by Roth (2024) in the framework of the Horizon2020 GLOBALINTO project. Our baseline model uses Roth's (2024) original model but differentiates the tangible capital term into tangible ICT capital and tangible non-ICT capital. This yields the following equation (1).

$$(1) \quad Q_{c,j,t} = Kict_{c,j,t}^{\alpha} Knict_{c,j,t}^{\beta} R_{c,j,t}^{\gamma} L_{c,j,t}^{\delta} A_{c,j,t} \varepsilon_{c,j,t}$$

where $Q_{c,j,t}$ is real value-added, $Kict_{c,j,t}$ is the tangible ICT capital stock, $Knict_{c,j,t}$ is the tangible non-ICT capital stock, $R_{c,j,t}$ is the intangible capital stock, $L_{c,j,t}$ is labor and $A_{c,j,t}$ is Total Factor Productivity (TFP) in country c in sector j at time t . The error term is denoted by $\varepsilon_{c,j,t}$ and it satisfies standard regularity assumptions. Dividing both sides of the equation by labor under the Cobb-Douglas assumption (that is, $\alpha+\beta+\gamma+\delta=1$) yields the following equation:

$$(2) \quad q_{c,j,t} = kict_{c,j,t}^{\alpha} knict_{c,j,t}^{\beta} r_{c,j,t}^{\gamma} A_{c,j,t} \varepsilon_{c,j,t}$$

Taking the logarithms of both sides and taking the first difference yield the following equation:

$$(3) \quad (\ln q_{c,j,t} - \ln q_{c,j,t-1}) = \alpha(\ln kict_{c,j,t} - \ln kict_{c,j,t-1}) + \beta(\ln knict_{c,j,t} - \ln knict_{c,j,t-1}) + \gamma(\ln r_{c,j,t} - \ln r_{c,j,t-1}) + (\ln A_{c,j,t} - \ln A_{c,j,t-1}) + u_{c,j,t}.^3$$

Applying Roth (2024), it is assumed that TFP growth shown by $(\ln A_{c,j,t} - \ln A_{c,j,t-1})$ in equation (3) has a common time-dependent factor across countries and sectors (μ_t) and a Nelson-Phelps (1966)-type control variable:

³ where: $u_{c,j,t} = \ln \varepsilon_{c,j,t} - \ln \varepsilon_{c,j,t-1}$.

$$(4) (\ln A_{c,j,t} - \ln A_{c,j,t-1}) = c + gH_{c,t} + mH_{c,t} \frac{(q_{max,t} - q_{c,t})}{q_{c,t}} + n(1 - ur_{c,t}) + p \sum_{i=1}^k X_{i,c,t} + \mu_t$$

Where c captures a constant, $H_{c,t}$ resembles Human Capital and captures the innovation capacity, $H_{c,t} \frac{(q_{max,t} - q_{c,t})}{q_{c,t}}$ represents a catch-up term, the term $(1 - ur_{c,t})$ resembles 1-unemployment rate and accounts for business cycles and $X_{i,c,t}$ refers to control variables i that might affect TFP growth in a country at time t . μ_t are time-fixed effects. Inserting equation (4) into equation (3), the following equation (5) is derived:

$$(5) (\ln q_{c,j,t} - \ln q_{c,j,t-1}) = \alpha(\ln kict_{c,j,t} - \ln kict_{c,j,t-1}) + \beta(\ln knict_{c,j,t} - \ln knict_{c,j,t-1}) + \gamma(\ln r_{c,j,t} - \ln r_{c,j,t-1}) + c + gH_{c,t} + mH_{c,t} \frac{(q_{max,t} - q_{c,t})}{q_{c,t}} + n(1 - ur_{c,t}) + p \sum_{i=1}^k X_{i,c,t} + \mu_t + u_{c,j,t}$$

Focusing on our four intangible capital variables as elaborated upon in section 2, the intangible term $(\ln r_{c,j,t} - \ln r_{c,j,t-1})$ from equation (5) is then separated into four different types of intangibles: research and development $(\ln rd_{c,j,t} - \ln rd_{c,j,t-1})$, software and databases $(\ln so_{c,j,t} - \ln so_{c,j,t-1})$, organizational capital $(\ln oc_{c,j,t} - \ln oc_{c,j,t-1})$, and vocational training $(\ln tr_{c,j,t} - \ln tr_{c,j,t-1})$ which leads to equation (6):

$$(6) (\ln q_{c,j,t} - \ln q_{c,j,t-1}) = \alpha(\ln kict_{c,j,t} - \ln kict_{c,j,t-1}) + \beta(\ln knict_{c,j,t} - \ln knict_{c,j,t-1}) + \gamma(\ln rd_{c,j,t} - \ln rd_{c,j,t-1}) + \lambda(\ln so_{c,j,t} - \ln so_{c,j,t-1}) + \zeta(\ln oc_{c,j,t} - \ln oc_{c,j,t-1}) + \iota(\ln tr_{c,j,t} - \ln tr_{c,j,t-1}) + c + gH_{c,t} + mH_{c,t} \frac{(q_{max,t} - q_{c,t})}{q_{c,t}} + n(1 - ur_{c,t}) + p \sum_{i=1}^k X_{i,c,t} + \mu_t + u_{c,j,t}$$

Consistent with the EU KLEMS methodology, the growth of capital inputs per labor is measured as capital services growth.

3.2. Data

For data, this paper uses the most recent release of the harmonized EUKLEMS/INTANProd 2022 dataset (Bontadini et al. 2023). This new release contains the internationally-harmonized data on tangible and intangible capital as utilized within this paper. In more detail, this paper uses the following data:

- Labour productivity growth is measured as real value added at constant 2015 prices divided by labour, which is measured as total hours worked by the number of people employed.
- Tangible ICT capital includes computing equipment (IT) and communications equipment (CT).

- Tangible Non-ICT capital includes transport equipment (TraEq), other machinery and equipment (OMach), and total non-residential investment (OCon). Following the existing literature, this analysis does not consider residential structures (RStruc) in constructing tangible capital.
- The intangible capital measure includes the two intangibles already recognized in the National Accounts: Computer Software and Databases (Software) and Research and Development (R&D). In addition, this paper also considers two intangibles not yet recognized in the National Accounts, but recognized important complementary intangible investment: Organizational Capital (OrgCap) and Vocational Training (Train).
- This analysis approximates human capital as educational attainment at the upper-secondary level and measures business cycles as the unemployment rate subtracted from one. These data are obtained from Eurostat.

3.3. Research Design

The base sample for this paper's econometric analysis consists of 14 EU-27 countries (Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Latvia, Lithuania, Netherlands, Slovakia, Slovenia, Spain, Sweden) and the United Kingdom over 1995-2019.

For its cross-country sectoral analysis, this paper considers that the market economy consists of the following sectors: Agriculture, forestry, and fishing (A); Mining and quarrying (B); Total manufacturing (C); Electricity, gas, steam and air conditioning supply (D); Water supply; sewerage; waste management and remediation activities (E); Construction (F); Wholesale and retail trade (G); Transportation and storage (H); Accommodation and food service activities (I); Information and communication (J); Financial and insurance activities (K); Professional, scientific and technical activities (M), Administrative and support service activities (N); Arts, entertainment, and recreation (R); and Other service activities (S).

Throughout the analysis, this paper differentiates between the goods-producing sectors (A-F) and the market service sectors (G-K, M-N and R-S).

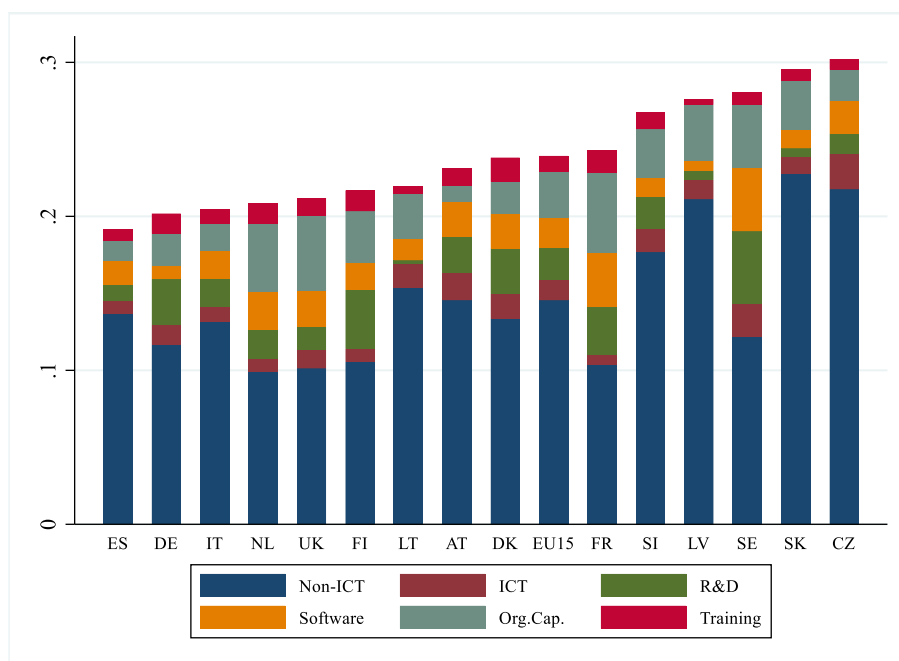
4. Descriptive Results

Figure 1 shows the investment rates over value added for our two tangible and four intangible capital variables in the market economy among the EU14 + UK. While the two new member states Czech Republic (CZ) and Slovakia (SK) display app. 30 percent of overall business capital investment by value added, the business investment rate in Spain is below 20 percent. Interestingly, tangible non-ICT capital is the dominating investment type among many of the EU14 economies, but in particular among the five new EU member states. In contrast, in the

highly advanced economies Sweden, France, Finland, the Netherlands and the UK business investment rates in intangible capital are much higher than in the five new member states.

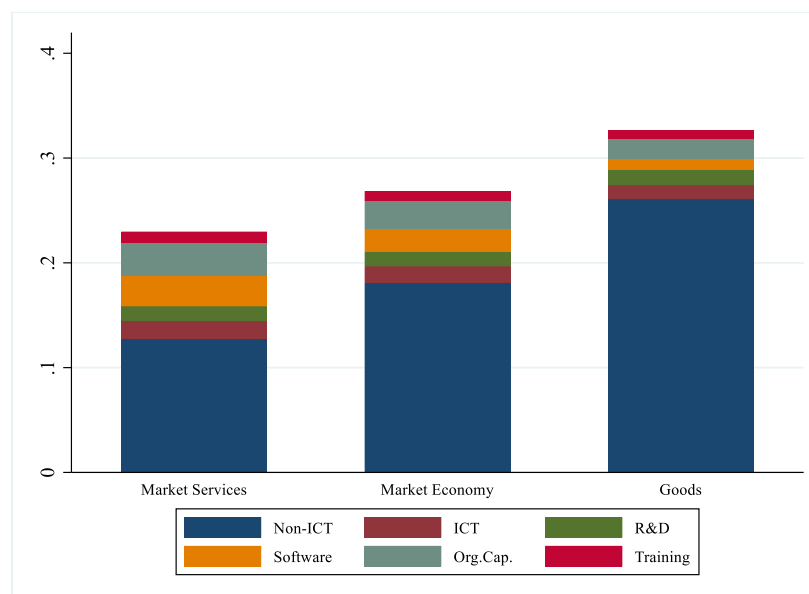
Figure 2 shows the business capital investment rate across the market economy and the broad sectors goods-producing and market services sector. The figure shows significant sectoral heterogeneity regarding the magnitudes and composition of business capital investment rates. While the goods producing sectors have much higher tangible non-ICT investment rates than the average, the market services have higher tangible ICT and intangible capital investments. Among the intangible capital investments we find that investments in organisational capital and software are the dominating types among market services. As can be detected from Figure A1 in the Appendix, the patterns for the goods producing sector is driven largely by the other goods sectors and the one for the market services by business services which shows the largest share of investment in intangible capital, even before the manufacturing sector with its large R&D investment.

Figure 1. Business Capital Investment Rates, EU14 + UK, 1995-2019



Sources: Author's own estimation based on the EU KLEMS 202 dataset (Bontadini et al. 2023). *Notes:* Investment rates are in percentage of VA and are obtained by dividing tangible and intangible investments by total value added in the business sector, excluding real estate. Investment rates represent time averages for each country. ICT= Information and Communication Technologies. R&D = Research and Development. OrgCap = Organisational Capital.

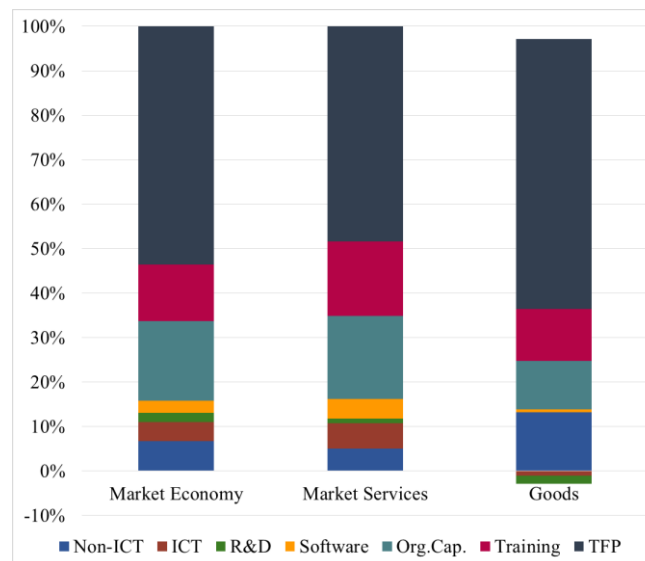
Figure 2. Business Capital Investment Rates across broad sectors, EU14 + UK, 1995-2019



Sources: Author's own estimation based on the EU KLEMS 2022 dataset (Bontadini et al. 2023). *Notes:* Investment rates are in percentage of VA and are obtained by dividing capital investments by the total value added of sectors. Investment rates represent average values across countries and years from 1995-2019. ICT= Information and Communication Technologies. R&D = Research and Development. OrgCap = Organisational Capital.

Figure 3 shows the results for a cross-country sectoral growth accounting exercise for our EU14 and UK country sample. Figure 3 clarifies three facts. First, on average in the sectors of the market economy of the EU14 and UK, Total Factor Productivity (54%) and intangible capital deepening (35%) explain the main share of labour productivity growth. Tangible capital deepening (11%) only plays a minor role. Second, among our four indicators of intangible capital, organisational capital plays the dominant role (18%), followed by training (13%), software (3%) and R&D (2%). Third, the sources of growth show very heterogeneous patterns within the market services and goods producing sectors. Whereas intangible capital deepening (41%) explains a somewhat similar large share than TFP (48%) in market services, the intangible capital share is much smaller in the goods producing sector (23%). More concretely, whereas investment deepening in organisational capital (19%) and training (17%) play the dominant role in the market services, investment deepening in non-ICT plays the dominant role in the goods producing sectors (14%).

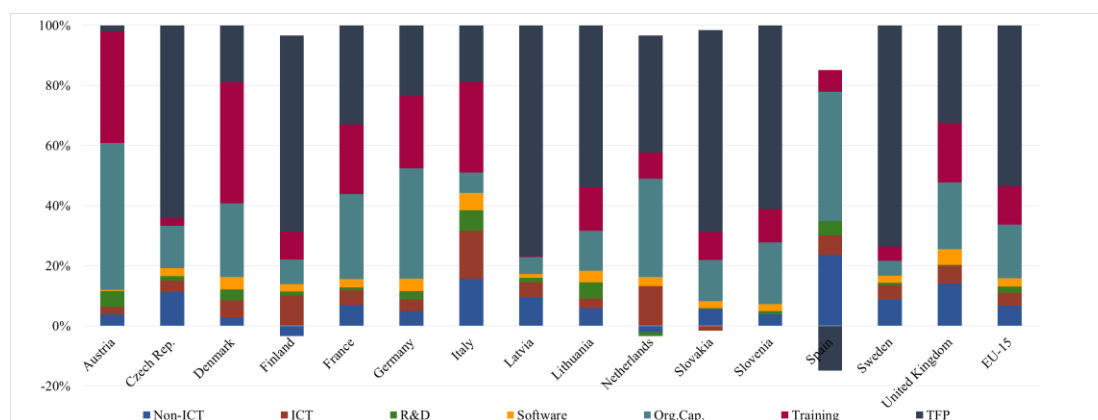
Figure 3. Cross-country sectoral growth accounting results across broad sectors, EU14 + UK, 1995-2019.



Sources: Author's own estimation based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat. *Notes:* The figure is based upon the econometric results of regressions 1-3 in Table 1. ICT=Information and Communication technology. R&D=Research and Development. OrgCap=Organisational Capital. TFP= Total Factor Productivity.

Figure 4 clarifies that the sources of growth show very heterogeneous patterns within industries of the market economy of the individual EU14 + UK countries. Whereas intangible capital deepening plays the dominant role in the industries of the market economy in Austria, Denmark, France, Germany, Italy, Spain and the United Kingdom, TFP plays the dominant role in the Czech Republic, Finland, Lithuania, Slovakia, Slovenia and Sweden. In the Netherlands, intangible capital deepening and TFP are equally important.

Figure 4. Cross-country sectoral growth accounting results across individual countries, Market Economy, EU-14 + UK, 1995-2019.



Sources: Author's own estimation based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat. *Notes:* The figure is based upon the econometric results of regressions 1 in Table 1. ICT=Information and Communication Technology. R&D=Research and Development. OrgCap=Organisational Capital. TFP= Total Factor Productivity.

5. Econometric Results

5.1 Econometric Estimation

In line with the existing literature (Niebel et al. 2017, Roth 2024) and the fact that the dataset at hand is one of small T (23) and large N (196) with a ratio of $T/N = 0.12$, in order to control for endogeneity, the baseline model in equation (6) is estimated using a dynamic panel estimation approach. Standard methods of dynamic panel estimation are the difference (Arellano and Bond, 1991) and the system (Arellano and Bover 1995; Blundell and Bond 1998; Bond et al. 2001) generalized method of moments (GMM). The two estimators have been designed for “small T , large N ” panels (Roodman 2009). While difference GMM transforms all regressors by differencing (Arellano and Bond 1991), the system GMM estimator augments the difference GMM estimator by building a system of two equations—the original equation and the transformed one (Arellano and Bover 1995; Blundell and Bond 1998; Bond et al. 2001). This permits the introduction of additional instruments and substantially improves efficiency (Roodman 2009, p. 86).

A practical test to assess whether to utilize difference or system GMM is introduced by Bond et al. (2001). The authors suggest that if the coefficients for the difference GMM estimation is below or close to the fixed effects estimation, then the instruments of the difference GMM estimator should be treated as weak, and the system GMM estimator should be utilized. Employing this test to our paper, we discover that the coefficients of our capital estimates for our difference GMM estimations are either below or similar to the fixed effects estimations.⁴ Adopting this logic by Bond et al. (2001), we determined to estimate equation (6) via a system GMM approach. For the implementation of the system GMM approach, we use the `xtabond2` command as developed by Roodman (2009, p. 121).

5.2 Econometric Results

Table 1 shows the econometric results when estimating equation (6) with the help of a System Generalized Method of Moments (GMM) estimation technique. Regression 1 in Table 1 shows the estimation results for an EU14 + UK cross-country sample over the 23-year period 1995-2019 with an overall number of 196 individual market economy sectors and 3,696 sectoral-time observations. It finds a statistically significant positive coefficient between tangible ICT capital and non-ICT capital services growth and LPG with elasticities of 0.12 and 0.021.

The estimates for our four intangible capital variables deliver mixed results. On the one hand, we find an insignificant relationship between research and development and LPG. This is in line with the latest findings by De Ridder (2024). On the other hand, we find a highly significant – although relatively small – relationship between software and databases and LPG. This is in line with the recent findings by Roth (2024).

⁴ Econometric results for the difference GMM estimations can be retrieved from the authors upon request.

Table 1. Tangibles, Intangibles and Labor Productivity Growth, System GMM Estimation at the Sectoral Level, EU 14 + UK, 1995-2019

	(1) FS ME	(2) FS Services	(3) FS Goods	(4) BC ME	(5) BC Services	(6) BC Goods	(7) AC ME	(8) AC Services	(9) AC Goods
ICT Capital	0.021* (1.93)	0.028** (2.03)	-0.0055 (-0.28)	0.027* (1.89)	0.013 (0.70)	0.025 (1.48)	0.021 (1.39)	0.043*** (3.01)	-0.027 (-0.89)
Non-ICT Capital	0.12*** (2.67)	0.088** (2.10)	0.25*** (2.71)	0.11 (1.65)	0.078 (1.11)	0.30*** (2.82)	0.11** (2.30)	0.074 (1.30)	0.10 (1.11)
Research & Development	0.017 (1.11)	0.0092 (0.57)	-0.016 (-0.36)	0.021 (0.91)	0.023 (0.79)	0.0034 (0.06)	0.016 (0.80)	0.011 (0.51)	0.0057 (0.09)
Software & Databases	0.032* (1.76)	0.050*** (3.00)	0.0083 (0.20)	0.054** (2.52)	0.057*** (3.07)	0.094** (2.21)	-0.0012 (-0.05)	0.061** (2.30)	-0.031 (-0.65)
Organizational Capital	0.18*** (4.74)	0.18*** (5.43)	0.11 (1.34)	0.31*** (3.92)	0.34*** (3.00)	0.16* (1.94)	0.12*** (3.34)	0.14*** (3.49)	0.12 (1.40)
Vocational Training	0.15*** (4.89)	0.20*** (4.97)	0.15* (1.89)	0.11* (1.82)	0.13 (1.65)	0.00025 (0.00)	0.15*** (4.19)	0.17*** (3.19)	0.17** (2.36)
Upper-Secondary Education	0.0010** (2.52)	0.00083 (1.42)	0.0015* (1.73)	0.00061** (2.13)	0.00061* (1.70)	0.00064 (1.26)	0.0014** (2.06)	0.0012 (1.47)	0.0023 (1.54)
Catchup	-0.00027 (-1.30)	-0.00042 (-1.33)	-0.000082 (-0.16)	-0.000010 (-0.05)	-0.000083 (-0.33)	0.00030 (0.77)	-0.00017 (-0.44)	-0.00037 (-0.78)	-0.00052 (-0.66)
Business Cycle	-0.20*** (-2.84)	-0.20* (-1.87)	-0.56*** (-3.05)	-0.15 (-1.51)	-0.14 (-0.98)	-0.34 (-1.16)	-0.29** (-2.26)	-0.22 (-1.63)	-0.59** (-2.31)
<i>First-Lag Instruments</i>	1 15	1 5	1 5	1 8	1 5	1 2	1 10	1 4	1 5
<i>No. Of instruments</i>	168	78	78	104	77	46	112	58	67
<i>AB Test AR(2)</i>	0.36	0.10	0.65	0.85	0.35	0.01	0.37	0.09	0.53
<i>Hansen Test</i>	0.20	0.22	0.29	0.22	0.30	0.17	0.20	0.28	0.18
<i>N Sectors</i>	196	126	70	162	107	55	196	126	70
<i>Time Series</i>	23	23	23	11	11	11	12	12	12
<i>Observations N xT</i>	3696	2415	1281	1584	1045	539	2112	1370	742

Sources: Authors' own estimations based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat. *Notes:* ***p < 0.01, **p < 0.05, *p < 0.1. Numbers in parentheses are t-ratios. Time dummies are included in every specification. Specification choices include the usage of a collapsed instrument set, orthogonal deviations, small-sample corrections, two-step estimation, and Windmeijr-corrected cluster-robust errors.

In contrast to the results for software, complementary intangible capital service growth for organisational capital and vocational training show highly significant and sizeable coefficients with elasticities as large as 0.18. These estimates can be interpreted as follows: a 1-percentage point increase in investments in organisational capital is associated with an increase in LPG by 0.18 percentage points. Such results align with Brynjolfsson et al.'s (2019, 2021) findings.

Concerning our control variables, we find a significant and positive relationship between the upper-secondary education rate and LPG. This complements the findings by Vandenbussche et al. (2006). In line with the literature, our business cycle variable is significantly and negatively related to LPG.

To better understand the sectoral dynamics behind our findings in regression 1, we estimate the market services sector in regression 2 and the goods-producing sector in regression 3. When differentiating between the two samples, we find that the market services sectors primarily drive the results for the market economy in regression 1. Our findings for the market services show highly significant and large coefficients for services growth in organizational capital (0.18), vocational training (0.20), software and databases (0.05), and ICT capital (0.03). Only the coefficient for non-ICT capital services growth is driven by the goods-producing sector with a coefficient of 0.25, double the size of one from regression 1 of 0.12.

To better understand the dynamics over time, we differentiate between a before-crisis sample from 1995 to 2007 in regressions 4-6 from an after-crisis sample from 2008 to 2019 in regressions 7-9. By applying this differentiation, we find some noteworthy results. The coefficient for non-ICT capital services growth of 0.12 in regression 1 is driven mainly by the before-crisis sample in the goods-producing sector (0.30). Organisational capital is more strongly driven by the before-crisis period (0.31), particularly from the market services sectors (0.34).

An interesting finding is connected to the relationship between vocational training and LPG. Whereas we find weakly significant and insignificant relationships between vocational training and LPG in the before-crisis sample, vocational training has the most considerable impact on LPG, with a coefficient of 0.15 throughout the after-crisis period. Interestingly, vocational training is significant for both the market services (0.17) and the goods-producing sectors (0.17).

5.3 Discussion

How do our results relate to the existing literature in this field? Three findings are worth mentioning and discussing.

First, similar to Roth (2024) we find that investments in tangible capital play a crucial role for LPG in the Goods sector. While the model specification in Roth (2024) did not differentiate between tangible ICT and tangible non-ICT capital, our paper, which conducts such a differentiation, finds that the non-ICT investments of tangible drive the results by Roth (2024). This suggests that investments in transport equipment, other machinery and equipment, and total non-residential assets still play a primary role in the goods-producing sector. As shown in Roth (2024) and Roth et al. (2023) and De Riddder (2024) and in Figure A1 in the Appendix, the manufacturing, and here in particular the high tech-manufacturing, should be somehow exempted from this finding given the importance of R&D for these particular sub-sectors.

Second, similar to Roth (2024), we find that LPG in the service sector benefits more from the non-R&D intangibles software, training, and organisational capital. In addition to Roth's (2024) findings, which do not differentiate between a pre-crisis and post-crisis period, our results clarify that in the case of training and ICT capital, such findings are driven by the period after the

economic crisis. In contrast, organizational capital impacted LPG throughout the 25 years of analysis. Such results align with Brynjolfsson et al.'s (2019, 2021) findings.

Third, once we combine the fact that the LPG gap between the EU and the US is located in lower LPG rates in the European service sectors together with our results that non-RD intangibles drive LPG in the service sector, we conclude that the LPG gap between the EU and the United States is strongly due to insufficient investment in non-R&D intangibles like software, training, and organisational capital. However, as highlighted in the most recent literature (Draghi 2024, Fuest et al. 2024) this does not imply per se that increasing investment in R&D wouldn't help catching up in terms of LPG with the US. In particular in the European high-tech sector R&D investments in AI will also be important to close the LP gap between the EU and the United States.

6. Conclusions

This paper analyses the critical drivers of labour productivity in the European Union (EU), differentiating between before and after the 2007 financial crisis, the goods and services sectors, ICT, and non-ICT tangible assets, as well as the four distinct intangibles R&D, training, software and organisational capital. Utilising the EUKLEMS 2022 dataset for 14 EU countries and the UK from 1995-2019, and employing growth regression analysis, we identify key factors contributing to productivity growth.

Our findings highlight the instrumental role of Research & Innovation (R&I) in enhancing EU labour productivity. Specifically, in the goods sector, productivity growth is predominantly driven by non-ICT tangible assets. Conversely, in the service sector, the non-R&D intangibles, software, training, and organisational capital emerge as the primary contributors to productivity improvements. Notably, the importance of training and ICT tangibles as drivers of productivity growth increases following the economic crisis, indicating a shift in the factors influencing productivity in the post-crisis period.

We argue that the productivity gap between the EU and the United States can be largely attributable to the EU's insufficient investment in non-R&D intangibles such as software, training, and organisational capital. Addressing this gap is crucial for the EU to enhance its economic competitiveness and sustain its socio-economic model.

To close this productivity gap and respond effectively to societal and environmental challenges, the EU should prioritise investments that offer the highest added value per euro spent. The analysis suggests that targeting investments in R&I, including organisational capital, training, software and ICT tangibles will be most effective. This approach is crucial for the EU to achieve its economic goals, maintain fiscal sustainability, and successfully implement the European Green Deal.

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Appendices

Appendix A: Additional Descriptive Statistics

Appendix B: Additional Econometric Findings

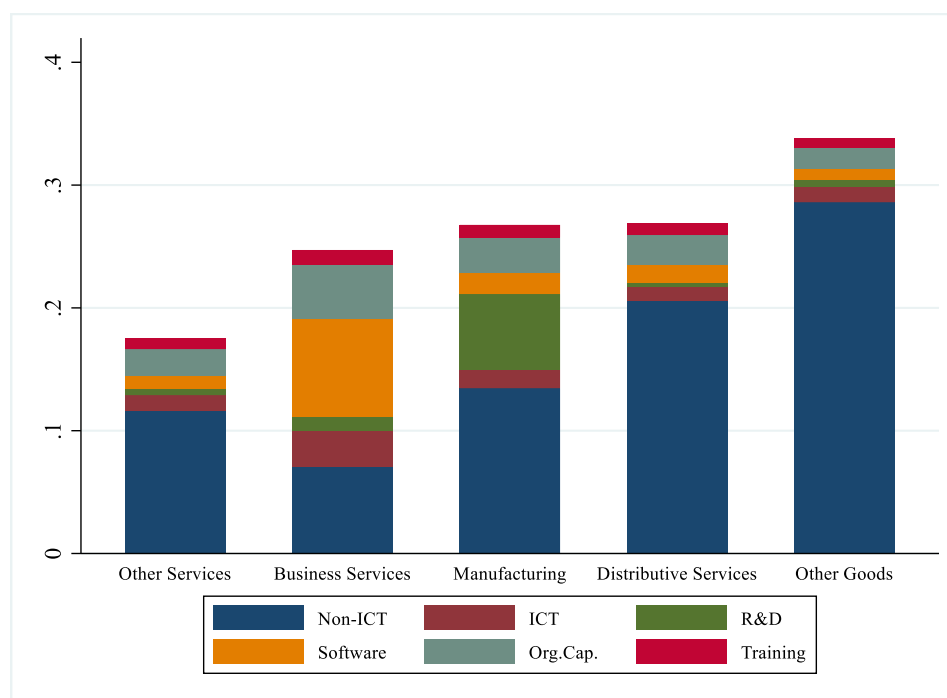
Appendix A: Additional Descriptive Statistics

Table A1. Summary Statistics

	Obs	Mean	Std. dev.	Min	Max
Labor Productivity Growth	3,696	0.010	0.062	-0.40	0.41
R&D per Labor Services Growth	3,696	0.021	0.12	-0.62	0.61
Organizational Capital per Labor Services Growth	3,696	0.019	0.055	-0.29	0.31
Software per Labor Services Growth	3,696	0.045	0.11	-0.58	0.66
Training per Labor Services Growth	3,696	0.010	0.061	-0.31	0.34
ICT Capital per Labor Services Growth	3,696	0.044	0.13	-0.92	1.55
Non-ICT Capital per Labor Services Growth	3,696	0.010	0.064	-0.68	1.48
Upper Secondary Education	3,696	75.75	13.95	33.7	95
Catchup	3,696	25.05	25.83	0	107.16
Business Cycle	3,696	0.92	0.040	0.74	0.98

Sources: Author's own estimation based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat.

Figure A1. Business Capital Investment Rates across sub-sectors, EU14 + UK, 1995-2019



Sources: Author's own estimation based on the EU KLEMS 2022 dataset (Bontadini et al. 2023). Notes: Investment rates are in percentage of VA and are obtained by dividing capital investments by the total value added of sectors. Investment rates represent average values across countries and years from 1995-2019. ICT= Information and Communication Technologies. R&D = Research and Development. OrgCap = Organisational Capital.

Appendix B: Additional Econometric Findings

Table B1. Tangibles, Intangibles and Labor Productivity Growth, Fixed-Effects Estimation at the Sectoral Level, EU 14 + UK, 1995-2019

	1	2	3	4	5	6	7	8	9
	FS	FS	FS	BC	BC	BC	AC	AC	AC
	ME	Services	Goods	ME	Services	Goods	ME	Services	Goods
ICT Capital	0.023** (2.20)	0.030** (2.33)	0.0089 (0.55)	0.024 (1.51)	0.0034 (0.14)	0.039** (2.01)	0.019 (1.19)	0.039** (2.41)	-0.012 (-0.47)
Non-ICT Capital	0.11*** (2.70)	0.075** (2.03)	0.21*** (2.79)	0.064 (1.20)	0.042 (0.95)	0.25* (1.96)	0.13*** (2.89)	0.10** (2.30)	0.19* (1.83)
Research & Development	0.031** (2.57)	0.030** (2.47)	0.022 (0.70)	0.020 (1.09)	0.032* (1.88)	-0.061 (-1.07)	0.038** (2.23)	0.031* (1.92)	0.052 (1.12)
Software & Databases	0.040*** (2.74)	0.042*** (3.04)	0.035 (1.15)	0.039** (2.30)	0.032* (1.81)	0.050 (1.40)	0.020 (0.87)	0.026 (1.11)	0.0055 (0.13)
Organizational Capital	0.18*** (5.94)	0.21*** (6.11)	0.13** (2.34)	0.33*** (4.41)	0.39*** (4.54)	0.14 (1.08)	0.16*** (4.29)	0.17*** (5.13)	0.14* (1.84)
Vocational Training	0.13*** (5.58)	0.17*** (5.50)	0.073* (1.73)	0.17*** (3.06)	0.18*** (2.81)	0.15 (1.41)	0.097*** (2.71)	0.13*** (2.80)	0.044 (0.74)
Upper Secondary Education	0.00052 (1.10)	0.00043 (0.88)	0.00092 (0.88)	0.00038 (0.44)	0.0011 (1.15)	-0.00061 (-0.35)	0.0013 (0.92)	-0.00086 (-0.61)	0.0046 (1.51)
Catchup	-0.00047** (-2.49)	-0.00059** (-2.47)	-0.00027 (-0.86)	-0.00036 (-1.25)	-0.00044 (-1.13)	-0.00017 (-0.49)	-0.0015*** (-4.53)	-0.0015*** (-4.40)	-0.0016** (-2.18)
Business Cycle	-0.16*** (-2.60)	-0.12* (-1.68)	-0.19 (-1.55)	-0.087 (-0.83)	-0.17 (-1.37)	0.081 (0.42)	-0.13 (-1.21)	-0.054 (-0.70)	-0.28 (-1.03)
R-squared	0.16	0.19	0.16	0.2	0.24	0.12	0.07	0.07	0.13
<i>N Sectors</i>	196	126	70	162	107	55	196	126	70
<i>Time Series</i>	23	23	23	11	11	11	12	12	12
<i>Observations N xT</i>	3696	2415	1281	1584	1045	539	2112	1370	742

Sources: Authors' own estimations based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat. Notes: ***p < 0.01, **p < 0.05, *p < 0.1. Numbers in parentheses are t-ratios. Time dummies are included in every specification.

Table B2. Tangibles, Intangibles and Labor Productivity Growth, Fixed-Effects Estimation, Manufacturing Sector, EU 14 + UK and EU9 + UK, 1995-2019

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	EU14+UK	EU14+UK	EU14+UK	EU14+UK	EU14+UK	EU9+UK	EU9+UK	EU9+UK	EU9+UK	EU9+UK
	Manuf. 1-D	Manuf. 2-D	High-Tech.	Med.-Tech.	Low-Tech.	Manuf. 1-D	Manuf. 2-D	High-Tech.	Med.-Tech.	Low-Tech.
ICT Capital	-0.024** (-2.62)	0.00056 (1.43)	0.00041 (1.12)	-0.097 (-0.91)	0.022 (1.16)	0.00087 (0.04)	0.00057 (1.37)	0.00032 (0.91)	-0.19 (-1.41)	0.0019 (0.06)
Non-ICT Capital	0.11 (1.02)	0.30 (1.65)	0.10 (1.22)	0.59*** (3.15)	0.015 (0.14)	0.19 (1.47)	0.42* (1.98)	0.13 (1.09)	0.66*** (4.31)	0.18** (2.25)
Research & Development	0.069* (1.82)	0.018 (0.30)	0.0041 (0.04)	0.022 (0.20)	0.093** (2.37)	0.18*** (4.11)	0.058 (1.05)	0.17*** (3.38)	0.027 (0.18)	0.095*** (3.81)
Software & Databases	0.021 (0.75)	-0.020 (-0.76)	0.029 (1.06)	-0.038 (-0.54)	-0.040 (-1.34)	-0.019 (-1.08)	-0.033 (-0.93)	0.0075 (0.22)	-0.0099 (-0.11)	-0.020 (-1.11)
Organizational Capital	0.068 (1.11)	0.21** (2.40)	0.15 (1.26)	0.47* (1.94)	0.085 (1.15)	-0.050 (-0.59)	0.11 (1.37)	-0.044 (-0.46)	0.53* (1.99)	-0.022 (-0.61)
Vocational Training	0.040 (0.64)	0.089 (0.86)	0.20 (1.58)	-0.077 (-0.38)	0.22* (2.02)	0.013 (0.17)	0.057 (0.47)	0.27** (2.38)	-0.14 (-0.62)	0.011 (0.12)
Secondary Education	-0.00093 (-0.94)	-0.0014** (-2.42)	-0.0014 (-1.53)	-0.0028 (-1.46)	-0.0014* (-1.86)	-0.00065 (-0.97)	-0.0013** (-2.24)	-0.0018** (-2.26)	-0.0030 (-1.40)	-0.0011* (-1.86)
Catchup	-0.00023 (-0.80)	-0.0000020 (-0.11)	-0.0000030 (-0.78)	-0.0000056 (-0.44)	0.000087*** (3.93)	-0.00020 (-0.30)	-0.0000037 (-0.19)	-0.00015 (-1.65)	-0.0000073 (-0.64)	0.000078*** (3.86)
Business Cycle	-0.36*** (-3.20)	-0.35*** (-4.13)	-0.43*** (-3.04)	-0.35** (-2.51)	-0.084 (-0.91)	-0.24** (-2.90)	-0.30*** (-3.34)	-0.36*** (-3.01)	-0.29** (-2.19)	-0.025 (-0.27)
R-Squared	0.25	0.07	0.09	0.09	0.06	0.34	0.07	0.08	0.10	0.05
N Sectors	15	124	55	27	31	10	102	45	23	25
Time Series	23	23	23	23	23	23	23	23	23	23
N	328	2553	1122	559	636	230	2192	950	494	552

Sources: Authors' own estimations based on the EU KLEMS 2022 dataset (Bontadini et al. 2023) and Eurostat. Notes: ***p < 0.01, **p < 0.05, *p < 0.1. Numbers in parentheses are t-ratios. Time dummies are included in every specification. Manuf.=Manufacturing. D.=Digits. Tech.=Technology. Med.=Medium.