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Intangible Capital and Labor Productivity Growth: Revisiting the Evidence*

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Abstract

This contribution analyzes the impact of intangible capital on labor productivity growth across countries at the aggregate and sectoral levels by employing an econometric growth-accounting approach. First, our results show that intangible capital deepening accounts for around 40 percent of labor productivity growth at both the aggregate and sectoral level. Second, we find that this positive impact of intangible capital on productivity growth at both levels of aggregation is driven by investments in economic competencies, the only intangible group not covered in the national accounts. Third, our results reveal deep sectoral heterogeneities regarding investments and productivity effects of different intangible types. These findings have important implications for future EU industrial policies and are directly relevant to the EU's efforts to close its productivity gap with the US.

Keywords: intangible capital, labor productivity growth, cross-country sectoral panel analysis, manufacturing, market services, EU

JEL Codes: C23, E22, L16, L60, L80, O47, O52

1. Introduction

The evidence on the role played by intangible capital in labor productivity growth remains inconclusive. Although most studies agree that intangible capital makes a positive contribution to labor productivity growth (LPG), a precise determination of this effect remains ambivalent. While traditional growth accounting studies find that intangible capital accounts for around 25 percent of labor productivity growth (Corrado *et al*., 2013), this magnitude stretches as far as 50 percent in studies that use an econometric cross-country growth accounting approach (Roth and Thum, 2013). In addition, evidence from most recent cross-country *sectoral* analyses remains equally ambivalent. Whereas some studies find a lower elasticity of intangible capital at the sectoral level vis-à-vis the existing cross-county studies (Niebel *et al.*, 2017), most recent studies present either negative (Piekkola, 2018) or insignificant and weak effects (Adarov and Stehrer, 2019) of intangible capital on labor productivity growth.

In this paper we conduct a cross-country sectoral analysis and investigate the impact of different intangibles on labor productivity growth. To this end, we use an econometric growth-accounting approach across countries and sectors by using the latest harmonized 2019 EU

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KLEMS data (Stehrer *et al*., 2019). Focusing on three different aggregation levels of the market economy for an EU-10 country sample for the period 1995-2017, our study produces three new results.

First, we find that intangible capital deepening accounts for around 40 percent of labor productivity growth at both aggregate and sectoral levels. Contrary to the existing studies in the literature (Niebel *et al*., 2017), our results reveal that intangible capital has a greater elasticity at the sectoral level than at the aggregate level. Second, when analyzing the three dimensions of intangible capital, we observe that the impact of intangible capital on labor productivity growth at aggregate and sectoral levels is largely driven by economic competencies. Our results therefore point out that the types of intangible capital that are omitted in the national accounts matter the most for labor productivity growth.

Third, our results reveal deep sectoral heterogeneities regarding the investment and productivity effects resulting from different intangibles. More specifically, R&D (research and development) makes up a large share of intangible capital investments and strongly impacts labor productivity growth in the manufacturing sector. On the other hand, investments in software and organizational capital in the market services sector constitute the majority of intangible investments. These two intangible types also exert strong effects on labor productivity growth in this sector.

Our findings have important implications for future EU industrial policies and are of direct relevance to closing the productivity gap between the EU and the US. The EU and individual members states should shift the focus of their competitiveness strategies in industrial policies, such as Europe 2020 (Gros and Roth, 2012), from a preoccupation with investments in innovative property – here mainly R&D – to a more holistic approach, which would include investments in software and economic competencies (Lampel *et al*., 2020). By focusing on the latter, the EU and its member states would be better able to address and further close the longstanding labor productivity growth gap vis-à-vis the US (Van Ark *et al*., 2008).

The remainder of the article is structured as follows. The next section presents the theoretical background to this topic and the evolving efforts to measure business intangibles. The third section reviews the evidence from existing cross-country aggregate and sectoral studies. The fourth section elaborates the model specification, the research design and the data used. The fifth section presents our descriptive statistics. The sixth section is devoted to our econometric results and a discussion of our results in the light of the previous research. And the final concluding section discusses the most salient policy implications of our findings.

2. Theoretical Background and Measuring Intangibles

The idea of intangible capital as a productive input dates back to the early 1960s (Haskel and Westlake, 2018), but its conceptualization and introduction to a neoclassical economic growth framework were realized only after the works by Nakamura (2001), Brynjolfsson *et al*. (2002) and the seminal contribution by Corrado, Hulten and Sichel (hereafter – CHS) (2005). CHS (2005) argued that since expenditures on intangibles represent foregone consumption today in order to increase output in the future, they should be counted as investments. Although the role of intangibles, especially R&D, in economic growth gained prominence with the endogenous growth literature (Romer, 1990; Grossman and Helpman, 1991 a,b; and Aghion and Howitt, 1992), the CHS (2005) framework sticks to the assumptions of the neoclassical growth model and does not feature the increasing-returns-to-scale and externalities properties associated with endogenous growth models.

Since the seminal study of Solow (1957) on the sources-of-growth, it is well known in the economics literature that the majority of economic growth can be attributed to a residual term called "total factor productivity" (TFP). Jorgenson and Griliches (1967), on the other hand, argue that if the heterogeneous character of productive inputs (e.g. capital and labor) are fully accounted for, a much smaller role will be left to TFP in explaining economic growth. From the methodology of Jorgenson and Griliches (1967), the inclusion of intangibles in an otherwise standard neoclassical growth function, as is done in CHS (2005), could be considered as an attempt to better measure the inputs. And therefore, the role of TFP in explaining economic growth will decline.

Since the publication of CHS (2005), there has been a proliferation of country studies aimed at measuring the impact of intangible capital on labor productivity growth (CHS, 2009, for the US; Marrano *et al*., 2009, for the UK; Fukao *et al*., 2009, for Japan). Similarly, many databases influenced by the CHS (2005) framework have been developed. The European Commission funded the FP7 INNODRIVE project to construct a comprehensive intangible capital dataset for an EU27 sample at the cross-country level (Gros and Roth, 2012; Roth and Thum, 2013). The official INNODRIVE macro dataset was then complemented by the INTAN-Invest (Rev. 1) (Corrado *et al*., 2013), the INDICSER (Niebel *et al*., 2017), the SPINTAN (Corrado *et al*., 2017b), and the INTAN-Invest (Rev.2) (Corrado *et al*., 2018) dataset, all of which have finally led to the official construction of the first harmonized EU KLEMS cross-country-(sectoral) dataset (Stehrer *et al*., 2019).[1]

Table 1. Measuring Business Intangibles in the EU KLEMS 2019 Dataset

No.	Dimension	Acc.	No.	Indicators	Acc.	NA
I.	Computerized Information	CI	1.	Computer Software and Databases	Software	Yes
II.	Innovative Property	IP	2.	Research and Development	R&D	Yes
			3.	Other Intellectual Property Products	OIPP	Yes
			4.	Design and Other Product Developments	D&O	No
III.	Economic Competencies	EC	5.	Advertising, Market Research and Branding	A&M	No
			6.	Vocational Training	VT	No
			7.	Purchased Organizational Capital	POC	No
			8.	Own-Account Organizational Capital	OOC	No

Notes: No.=Number, Acc.=Acronyms. NA=National Accounts.
Sources: CHS (2005) and Stehrer *et al*. (2019).

Table 1 gives an overview of 2019 EU KLEMS dataset. Following the CHS (2005) framework, the dataset contains three dimensions (I. Computerized Information, II. Innovative Property and III. Economic Competencies), with eight overall indicators of intangible capital: 1. Computer Software and Databases (Software), 2. Research and Development (R&D), 3. Other Intellectual Property Products (OIPP), 4. Design and Other Product Developments (D&O), 5.

[1] An overview of each of these datasets is provided in the supporting information in Table C1.

Advertising, Market Research and Branding (A&M), 6. Vocational Training (VT), 7. Purchased Organizational Capital (POC) and 8. Own-Account Organizational Capital (OOC). Whereas Software, R&D and OIPP have already been included in the National Accounts, D&O, A&M, VT, POC and OOC have yet to be incorporated.

3. Cross-Country Sectoral Evidence

Table 2 gives an overview of the existing cross-country aggregate and sectoral studies that analyze the relationship between intangible capital and labor productivity growth. We identified a total of seven studies in this field of research with direct relevance to our study: three at the aggregate level (Corrado *et al.*, 2013; Roth and Thum, 2013; Roth, 2020) and four at the sectoral level (Corrado *et al.*, 2016; Niebel *et al.*, 2017; Piekkola, 2018; Adarov and Stehrer, 2019). Given the cross-country focus of our analysis, Table 2 omits aggregate (e.g. CHS, 2009, for the US; Marrano *et al*., 2009, for the UK; Edquist, 2011, for Sweden) and sectoral studies (Crass *et al*., 2015, for Germany; Delbecque *et al*., 2015, for France; Dal Borgo *et al*., 2013, for the UK) for individual countries. Table 2 also omits cross-country sectoral studies that focus on complementarities and spill-over effects of intangible capital investments (Chen *et al*., 2016; Corrado *et al*., 2017a).

The first study by Roth and Thum (2013) utilizes an econometric cross-country growth accounting estimation approach. It uses INNODRIVE data (Gros and Roth, 2012) for an EU-13 country sample over the time period 1998–2005 and finds that business intangible capital deepening is the dominant contributor to labor productivity growth in the market economy with a magnitude of nearly 50 percent. This magnitude is almost twice as large as the one from individual country studies using the traditional growth accounting approach (CHS, 2009; Marrano *et al*., 2009; Fukao *et al*., 2009; c.f. Edquist, 2011). Intangible investment makes up around for 10%.

The cross-country study by Corrado *et al*. (2013) uses INTAN-Invest (Rev. 1) data for an EU-15 and the US sample over the time period 1995-2007 and estimates the impact of intangible capital on labor productivity growth using the growth accounting methodology. They find that the EU invests less in intangibles (6.6 percent of GDP) than the US (10.6 percent of GDP). Their results on the magnitudes of intangible capital deepening on labor productivity growth (23.8 percent for the EU-15 and 24.8 percent for the US) largely confirm findings of growth accounting studies for individual countries (CHS, 2009; Marrano *et al*., 2009; Fukao *et al*., 2009; c.f. Edquist, 2011).

The third study is a growth econometric study by Roth (2020) using INTAN-Invest (Rev. 2) data for an EU-16 country sample for the time period 2000-2015. Depending on the inclusion/exclusion of an Irish dummy for the year 2015, the coefficient for intangibles varies from 0.26 to 0.38 and respectively explains 46 to 66 percent of labor productivity growth. Such a magnitude is almost twice as strong as the one found by Corrado *et al*. (2013) or the existing individual country case studies. Intangible investment rate equals to 11% of GVA.

Because of the availability of sectoral data from recently-released datasets on intangibles, including the INDICSER, INTAN-Invest (Rev. 2) and EU KLEMS 2019, recent studies can also approach the relationship between intangible capital and labor productivity growth from a sectoral perspective (Corrado *et al*., 2016; Niebel *et al*., 2017; Piekkola, 2018; Adarov and Stehrer, 2019). The fourth study by Corrado *et al*. (2016) applies a growth accounting methodology to quantify the role of intangible capital on labor productivity growth at the sectoral level. Similar to the growth accounting studies at the country level (Corrado *et al*., 2013), the authors find that intangible capital deepening explains around 20-25 percent of productivity growth at the sectoral level. They also conclude that no noticeable difference exists between the manufacturing and services regarding the contribution of intangible capital deepening to labor productivity growth. In their econometric estimations, they find a statistically significant elasticity of 0.27 for non-R&D intangible capital, but an insignificant elasticity for R&D of 0.07. They also find that whereas R&D investment intensity is high in manufacturing, non-R&D intangible investment is high in services.

The fifth study by Niebel *et al*. (2017) looks at the role of intangible capital on labor productivity growth at the sectoral level for 10 EU countries for the period 1995 to 2007. Although they find in their econometric estimates statistically significant and positive elasticities of intangible capital at the sectoral-level that are greater than its factor share, they finally conclude that the sectoral estimates for intangible capital suggest a lower elasticity than that had been found in previous studies, including Roth and Thum (2013). Although they do not state what their econometric estimates imply for the growth accounting quantitatively, their results suggest that intangible capital deepening probably accounts for less than 50 percent of labor productivity growth. Similar to Corrado *et al*. (2016), they find no noticeable difference in the elasticity of intangible capital between the manufacturing and market service sectors. They find the highest intangible capital investment rates in manufacturing, business services and finance sectors.

The sixth study by Piekkola (2018) does not give strong support to the idea that intangible capital impacts labor productivity growth positively at the sectoral level. The author extends the coverage of countries to EU28, and he also covers the post-crisis period (2008-2013) in his sectoral analysis of intangible capital. He concludes that intangible capital contributed negatively to labor productivity growth during the crisis period.

The seventh study by Adarov and Stehrer (2019) uses the November 2019 release of theh EU KLEMS dataset. Using a sample of EU28 countries in addition to the US and Japan, their analysis reveals that classical productive inputs such as tangible capital and labor still largely account for labor productivity growth. Although they indicate that advertising, market research and branding have a positive effect on LPG, their results make a weak case for the importance of intangible capital. Overall, their results at the sectoral level show either insignificant or weak results.

In short, the cross-country aggregate and sectoral econometric studies listed in Table 2 report ambivalent findings about the impact of intangible capital on labor productivity growth. Our study aims to clarify some of this ambivalency found in the literature. We contribute to the state of the art in several important ways. First, we compare the existing results from previous growth accounting and econometric studies, by applying an econometric growth accounting approach to quantifying the impact of intangibles. And, secondly, to better understand the drivers of aggregate productivity, we analyze the investment rates and labor productivity growth effects of intangible capital at three different levels of aggregation, and we also analyze the market economy at different aggregation levels.

Table 2. Summary of Cross-Country Aggregate and Sectoral Studies on Intangibles and Productivity Growth

No.	Authors	Countries	Method	Time Period	Coverage	Data Source(s)	CRS	Elasticity of IC	Main Results
Cross-Country									
1	Roth and Thum (2013)*	EU13	CCGA	1998-2005	Market Economy excluding Agriculture	INNODRIVE, EUKLEMS, Eurostat	Yes	0.29	Intangible investment makes up around for 10% of GVA in EU13 countries. The econometric cross-country growth accounting shows that intangible capital explains 50% of LPG.
2	Corrado *et al.* (2013)*	EU15,US	GA	1995-2007	Market Economy	INTAN-Invest (Rev. 1), EUKLEMS	Yes	-	EU15 invests less than the US on intangibles (6.6% vs. 10.6% of GVA). Intangible capital deepening accounts for 23.8% of LPG in the EU and 28.4% of that in the US.
3	Roth (2020)*	EU16	CCGA	2000-2015	Market Economy excluding Agriculture	INTAN-Invest (Rev. 2), EUKLEMS, Eurostat	Yes	026-0.38	Intangible investment rate equals to 11% of GVA. The growth accounting based on econometric estimations shows that intangible capital deepening accounts for 46% to 66% of LPG.
Cross-Country Sectoral									
4	Corrado *et al.* (2016)*	EU12	GE (OLS and IV)	1995-2010	Market Economy	National Accounts, INTAN-Invest	Yes	0.07, 0.27	Intangible capital deepening explains around 20-25% of LPG. No differences exist between the manufacturing and services regarding the impact of intangible capital deepening.
5	Niebel *et al.* (2017)*	EU11	GA and GE (POLS, LSDV, FE, GMM-SYS)	1995-2007	Market Economy	EUKLEMS, INDICSER	No	0.174	Their intangible capital elasticity estimations are smaller than found in the macro-studies. The highest intangible capital investment rates are found in the manufacturing, the business services and finance sectors.
6	Piekkola (2018)*	EU20, NO	GA and GE (POLS, MG, CCE, WLP)	2008-2013	Market Economy	Own constructed dataset from EUROSTAT indicators	Yes	0.3	Intangible capital deepening contributes negativelty to labor productivity growth during the crisis period (2008-2013).
7	Adarov and Stehrer (2019)	EU20, JP, NO, US	GA and GE (FE, POLS, GMM-SYS)	2000-2017	Total Economy	EUKLEMS 2019 Release	No	-	Intangibles overall do not have a statistically significant effect on labor productivity and real value added growth except for advertising and marketing.

Notes: * SSCI Peer Review Article. GA=Growth Accounting, CCGA=Cross-Country Growth Accounting, GE= Growth Econometrics, POLS=Pooled Ordinary Least Squares, LSDV=Least Squares Dummy Variables, FE=Fixed-Effects Regression, GMM-SYS=System GMM Regression, MG=Mean Group Estimator, CCE=Common Correlated Effects Estimator, WLP=GMM as Wooldridge Modified Petrin-Levinson Estimator, RVA=Real Value Added, EU=European Union. CRS=Constant Return to Scales. IC=Intangible Capital. No.=Number.

4. Model Specification, Research Design and Data

4.1. Model Specification

We consider the following production function as developed by Roth and Thum (2013) for the aggregate level and enhance it for the *sectoral* level:

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

where $Q_{c,j,t}$ is real value added, $K_{c,j,t}$ is the tangible capital stock, $R_{c,j,t}$ is the intangible capital stock, $L_{c,j,t}$ is labor, and $A_{c,j,t}$ is 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, α+β+γ=1) yields the following equation:

(2) $$q_{c,j,t} = A_{c,j,t}k_{c,j,t}^{\alpha}r_{c,j,t}^{\beta}\varepsilon_{c,j,t}$$

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

(3) $$(\ln q_{c,j,t} - \ln q_{c,j,t-1}) = \left(\ln A_{c,j,t} - \ln A_{c,j,t-1}\right) + \alpha(\ln k_{c,j,t} - \ln k_{c,j,t-1}\big) + \beta\big(\ln r_{c,j,t} - \ln r_{c,j,t-1}\big) + u_{c,j,t}.$$ [2]

Applying Roth and Thum (2013) to the cross-country *sectoral* level, we assume that TFP growth shown by $(\ln A_{c,j,t} - \ln A_{c,j,t-1})$ in Equation (3) has a time-dependent common factor across countries and sectors (μ_t) and a Nelson-Phelps (1966)-type control variable:

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

Where c captures a constant, $H_{c,t}$ captures the innovation capacity, $H_{c,t}\frac{(q_{max.t} - q_{c,t})}{q_{c,t}}$ represents a catch-up term, the term $(1 - ur_{c,t})$ accounts for business cycles and $X_{i,c,t}$ refers to control variables *i* that might effect TFP growth in a country at time t. μ_t are time-fixed effects. Inserting Equation (4) into Equation (3) we derive the following:

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

In estimating Equation (5), we match $q_{c,j,t}$ as the growth in value added at constant prices. Consistent with the EU KLEMS methodology, the growth of capital inputs $(k_{c,j,t}, r_{c,j,t})$ per labor is measured as the capital services growth. For a calculation of tangible and intangible services growth, see the supporting information in Appendix D.

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

4.2. Research Design

The base sample for our econometric analysis consists of ten EU-15 countries[3] (Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and the UK – the EU10) over the time period 1995-2017. We decided to exclude the new member states (NMS)[4] from our base sample given the strong transition dynamics they experienced in their goods sectors during this period, with increases in tangible capital investments. We still include them, however, and the US for benchmark purposes within our descriptive statistics and also in our robustness analysis.[5] A list with the selection criteria for all countries can be found in Table C2 in the supporting information.

For our cross-country sectoral analysis, we consider 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; repair of motor vehicles and motorcycles (G); Transportation and storage (H); Accommodation and food service activities (I); Information and communication (J); Financial and insurance activities (K); Professional, scientific, technical, administrative and support service activities (M-N); Arts, entertainment and recreation (R); and Other service activities (S).[6] Throughout our analysis we differentiate between the goods-producing sectors (A-E) and the market service sectors (F-K, M-N, R and S) [see here Table C3 in the supporting information].

We also differentiate five sub-sectoral categories: i) manufacturing (C); ii) other goods (A,B,D,E,F); iii) distributive services (G,H); iv) business services (J,K,M-N); and v) other services (I,R,S). This choice was made to ensure feasibility, as it also reflects the intangible capital intensities of sectors. In the case of the goods sector, we decided to separate the manufacturing sub-sector from the others in the sector since it is materially more knowledge-intensive. For similar reasons, we decided to separate the knowledge-intensive Business/IC/Finance services from the distributive services within the market services sector. The remaining service industries with low productivity growth are categorized as Other Services (see here Table C4 in the supporting information).

[3] Because of data limitations at the sectoral level, our study does not include Belgium, Greece, Ireland, or Portugal. Moreover, we exclude Luxembourg from our analysis as it behaves as an outlier.

[4] The eight NMS with sectoral data coverage include the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Slovakia, and Slovenia. The five NMS with insufficient sectoral data include Bulgaria, Croatia, Cyprus, Malta and Poland.

[5] In addition, we have replicated all descriptive and econometric results for the NMS, which are available upon request to the authors.

[6] We omit Real estate activities (L); Public administration and defense, compulsory social security (O); Education (P); and Health and social work (Q). Due to a lack of data, we also do not consider sectors such as Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (T) and Activities of extraterritorial organizations and bodies (U).

4.3. Data

For data we use the November 2019 release of the EU KLEMS.[7] This new release contains most of the internationally-harmonized data on tangible and intangible capital needed for this study, which thus constitutes the main reason why we chose to base our analysis on this dataset.[8] We use the following data within our analysis:

- Labor productivity growth is measured as real value added at constant 2010 prices divided by the labor, which is measured as total hours worked by the number of people enployed.[9]

- Tangible capital includes computing equipment (IT), communications equipment (CT), transport equipment (TraEq), other machinery and equipment (OMach), and total non-residential investment (OCon). Following the existing literature, we do not take residential structures (RStruc) into account in the construction of tangible capital (see here also Table C5 in the supporting information).

- Our intangible capital measure includes intangibles already recognized in the National Accounts such as Computer Software and Databases (Software), Research and Development (R&D), and Other IPP assets (OIPP).[10] In addition, we also consider Advertising, Market Research and Branding (A&M), Design and Other Product Developments (D&O), Purchased Organizational Capital (POC) and Vocational Training (VT) (see here also Table C5 in the supporting information).[11]

- These intangibles are further categorized under three dimensions: I. Computerized Information contains Software; II. Innovative Property contains R&D and D&O; III. Economic Competencies contain A&M, POC and VT (see here also Table 1).

- We approximate human capital as educational attainment at the upper secondary level and measure business cycles as unemployment rate subtracted from one. These data are obtained from Eurostat.

- Among the control variables included in the robustness analysis are: rule of law, openness to trade, FDI, government expenditures, social expenditures, inflation, income tax, and stock market capitalization. These variables are obtained from Eurostat and the World Bank.

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[7] The dataset can be downloaded at: https://euklems.eu/. As we prepare this draft, an update of the EU KLEMS dataset is underway.

[8] For example, the INTAN-Invest data (Rev.2) does not provide capital stock data (see here e.g. Roth, 2020).

[9] Labor input is measured as total hours worked by people engaged, and we therefore abstain from making qualitative changes in the labor input. We believe that it is a necessary assumption to match our estimates with the aggregate-level analyses where such labor quality input changes are usually taken into account.

[10] Owing to insufficient data coverage at the sectoral level, OIPP was excluded from our econometric analysis.

[11] Owing to insufficient data coverage at the country level, own-account organizational capital (OOC) was excluded from our descriptive and econometric analysis.

5. Descriptive Analysis

Table 3 shows the labor productivity growth rates for the market economy at the country and sectoral levels for an EU10 country sample over the period 1995-2017. We included the US and an aggregate measure for the NMS for benchmark purposes. Table 3 points out that labor productivity growth rates among the EU10 vary considerably. Whereas the Scandinavian economies Sweden and Finland show relatively high growth rates (greater than 2 percent per year), the Mediterranean economies Italy and Spain show relatively low productivity growth rates (lower than 0.6 percent per year). The coordinated economies Austria, France, Germany, and the Netherlands, as well as the liberal market economy the UK and the Scandinavian economy Denmark exhibit growth rates close to the EU10 average of 1.51 percent. At 2 percent, the US growth rate is higher than the EU10 average but lower than those of Sweden and Finland. Due to their ongoing convergence process, NMS exhibit the largest growth rates with 4.03 percent.

Table 3. Aggregate and Sectoral Labor Productivity Growth Rates: EU10, 1995-2017 (%)

	Market Economy	Goods	Market Services	Other Goods	Manu-facturing	Distributive Services	Business Services	Other Services
EU10*	1.51	1.88	1.16	0.78	2.70	1.52	1.19	0.17
Austria	1.73	2.50	1.13	1.54	2.94	1.66	1.36	0.18
Denmark	1.45	1.94	1.16	0.95	2.90	1.44	1.16	0.12
Finland	2.11	2.96	1.30	1.84	3.58	2.07	1.47	-0.14
France	1.46	1.52	1.10	-0.12	3.10	1.45	1.16	0.45
Germany	1.53	2.26	0.96	1.37	2.43	1.64	1.16	0.65
Italy	0.43	0.68	0.19	-0.11	1.26	0.48	0.25	-0.15
Netherlands	1.49	1.74	1.47	0.61	2.77	1.69	1.18	0.19
Spain	0.59	1.48	0.09	1.23	1.69	0.58	0.63	-0.05
Sweden	2.75	2.75	2.67	0.42	4.19	2.75	2.11	0.03
UK	1.58	1.22	1.77	0.10	2.36	1.58	1.47	0.46
USA	2.00	2.21	1.93	0.61	3.42	1.96	1.77	0.50
NMS**	4.03	4.73	2.95	3.60	5.42	3.51	2.19	0.64

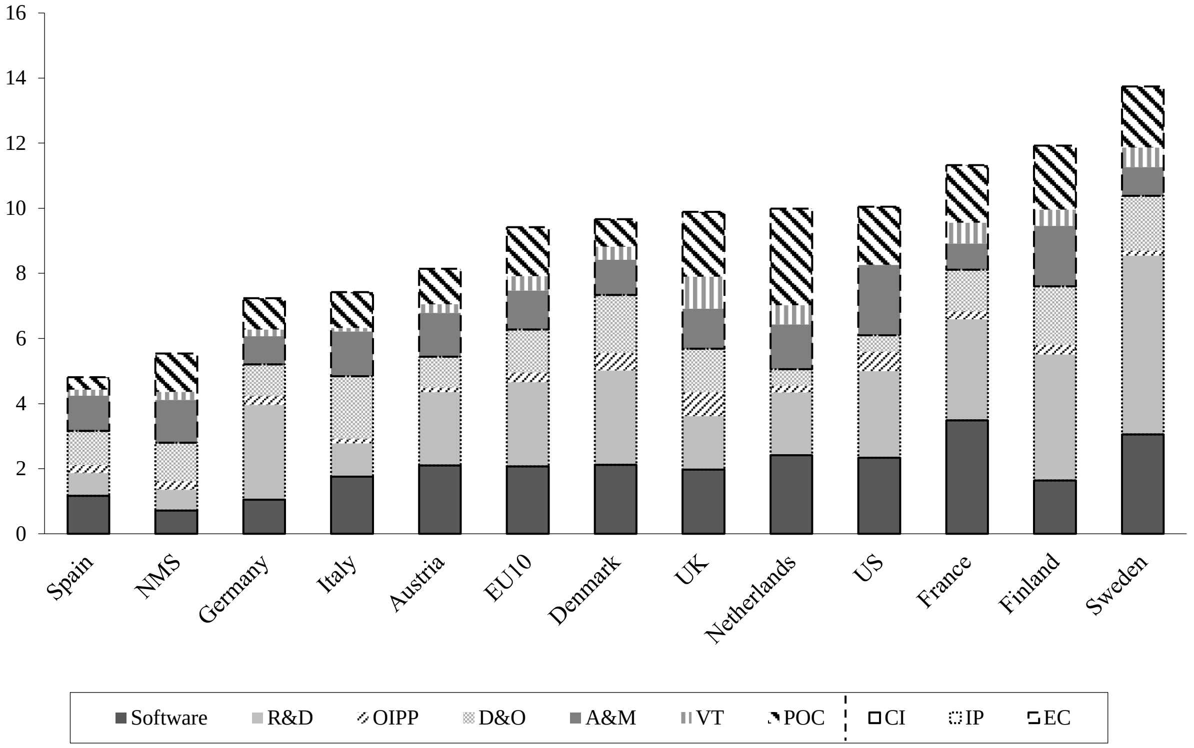
Notes: *EU10 refers to the ten EU countries analyzed in this study. ** Data for NMS reflect the period 2000-17.
Source: Authors' own estimations based on EU KLEMS (Stehrer *et al*., 2019).

Our analysis of the growth patterns for the sectoral level clarifies that all EU10 economies, with the exception of the UK, show higher growth rates in the goods sector than in the market services sectors. While the productivity growth difference between these two sectors is low in countries such as Sweden and the Netherlands, it is particularly high in countries such as Germany and Finland. In relation to the US, we observe that productivity growth differences between the US and EU10 are greater in the market services sector than in the goods sector.

Further disaggregation into the five sectoral classifications clarifies that manufacturing is the sector with the greatest labor productivity growth rate, while the other services display the lowest labor productivity growth rates among the EU10 economies. We also find that the growth difference between the EU10 and the US is greatest in the manufacturing sector, followed by the business and distributive services sectors. With the exception of Sweden and

Finland, all EU10 economies register an inferior performance in these three sectors, with Italy and Spain displaying particularly low productivity growth rates. Table B1 in the supporting information provides more disaggregated sectoral information for additional time periods: 1995-2007, 2008-2013 and 2014-2017.

Figure 1. Business Intangible Capital Investment (as a percentage of VA), EU10, 1995-2017



Notes: Investment rates are obtained by dividing intangible investments by total value added in the business sector excluding real estate. Investment rates represent time averages for each country. R&D = Research and Development, OIPP = Other Intellectual Property Products, D&O = Design and Other Product Developments, A&M = Advertising, Market Research and Branding, VT = Vocational Training, POC = Purchased Organizational Capital, CI = Computerized Information, IP = Innovative Property, EC = Economic Competencies.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

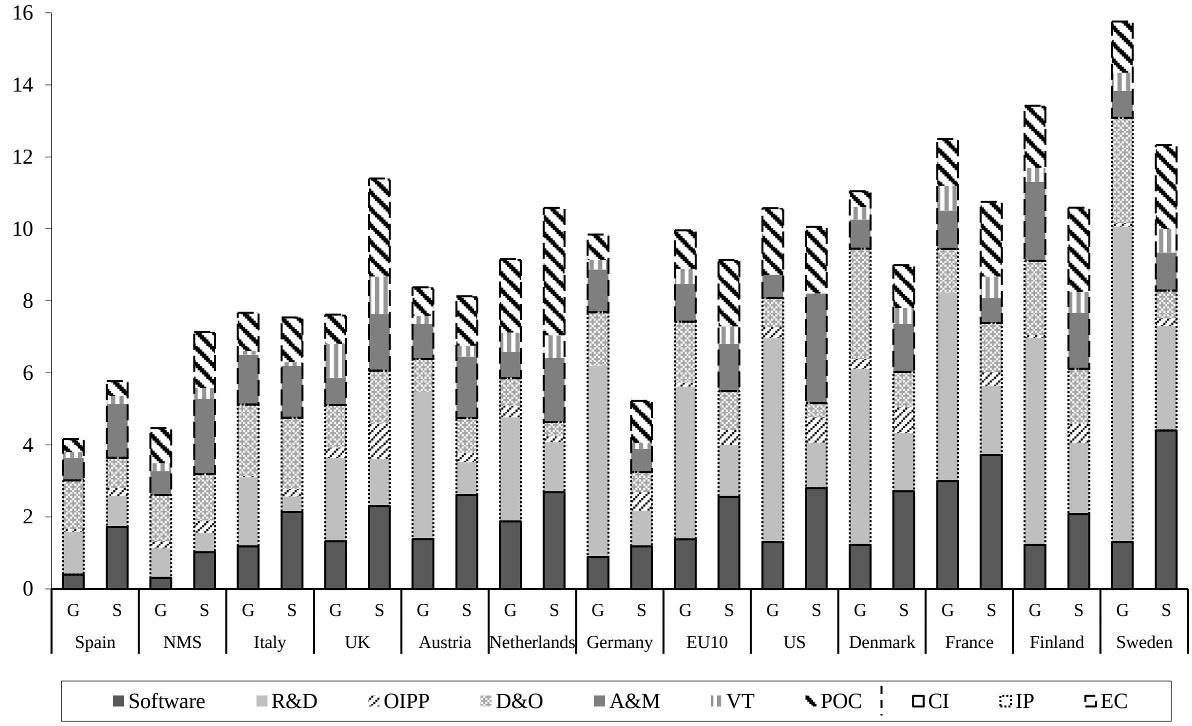
Figure 1 shows intangible investment rates over value added in the market economy among the EU10, the US and the NMS.[12] While Sweden and Finland invest around 12-14 percent in intangible capital, investment rates in Spain, Germany[13] and Italy range between 5 to 8 percent.[14] The EU10 average investment rate of 9.4 percentis slightly lower than that of the US, at 10.5 percent, as well as slightly lower than the evidence indicated by INNODRIVE data, with 9.9 percent (Roth and Thum, 2013), and INTAN-Invest (Rev. 2) data, with 11 percent (Roth, 2020) – see here also Table 2. We observe that investments in innovative property,

[12] Figure B1 in the supplementary information shows all EU18 cases including the eight individual NMS.
[13] It should be noted here that micro data from the Mannheim Innovation Panel (MIP) suggest that investment rates in intangible capital are significantly higher (Roth *et al*., 2021).
[14] As can be seen from Figure B2 in the supporting information, the high/low investment rates in intangibles are strongly associated with high/low labor productivity growth displayed in Table 3. In addition, when adding intangibles to tangibles, an intangible/tangible capital ratio of 0.71 for the EU10 indicates that intangible capital investments have nearly approached those in tangible capital (see here Figure B3 in the supplementary information).

particularly in R&D, constitutes the largest part of investments in most EU10 economies, followed by investments in economic competencies, in particular organizational capital.[15]

We analyze this heterogeneity in investments patterns further in Figure 2 by looking at the composition of investments in the goods and services sectors. First, we observe that in a majority (7 out of 10) of economies, intangible capital investment rates are greater in the goods sector than the services sectors. The three economies Spain, the Netherlands and the UK, however, have larger investments in intangible capital in the market services.

Figure 2. Business Intangible Investment (as a percentage of VA) – Goods vs. Services Sectors



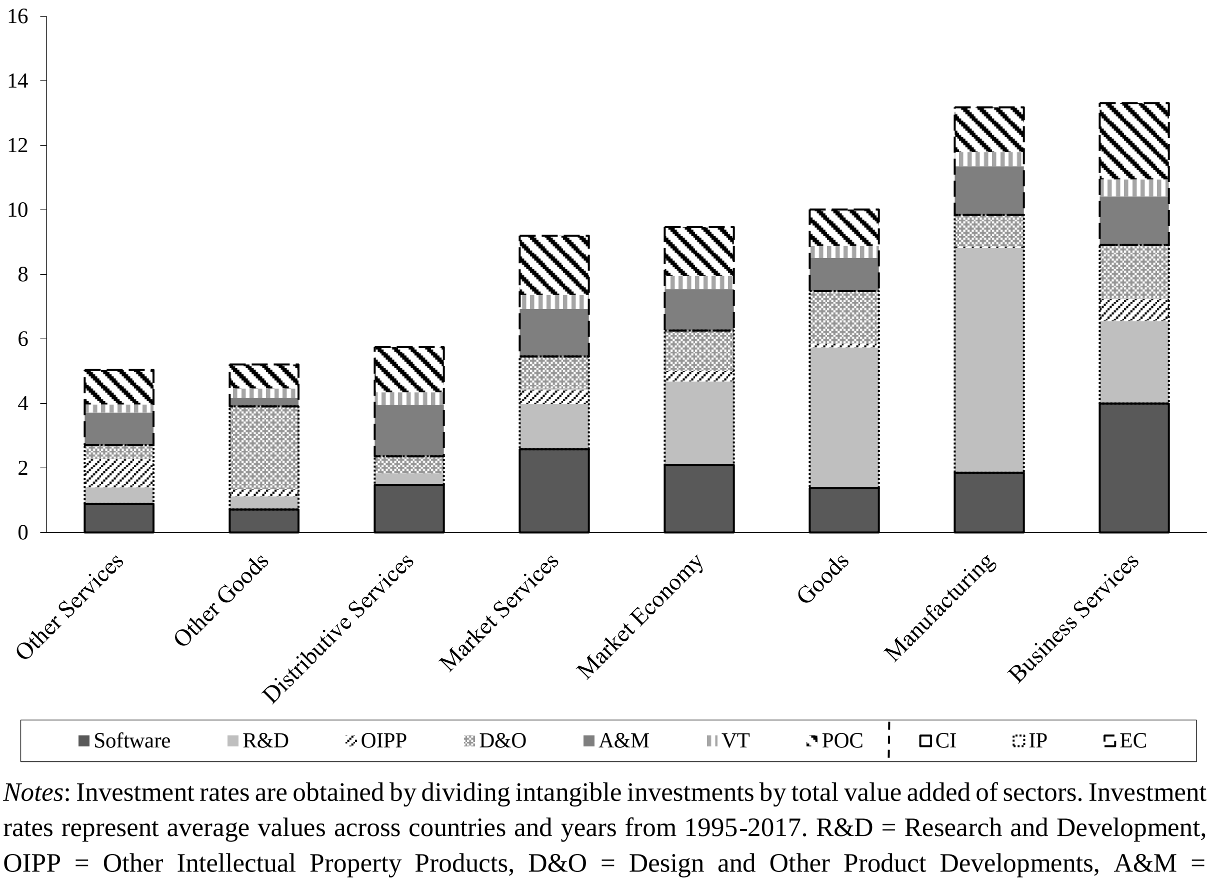
Notes: Investment rates are obtained by dividing intangible investments by total value added in goods and market services sector. Investment rates represent time averages for each country from 1995-2017. Countries grouped from left to right with respect to intangible investment in goods. G=Goods Sector, S=Services Sector, EU=European Union, NMS=New Member States, R&D = Research and Development, OIPP = Other Intellectual Property Products, D&O = Design and Other Product Developments, A&M = Advertising, Market Research and Branding, VT = Vocational Training, POC = Purchased Organizational Capital, CI = Computerized Information, IP = Innovative Property, EC = Economic Competencies.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Our results also point out a great heterogeneity regarding the composition of intangible capital investments at the sectoral level. Whereas R&D investments largely dominate intangible capital investments in the goods sector, investments in software and organizational capital dominate overall intangible capital investments in market services. Our finding regarding the dominance of R&D investments in the goods sector is in line with previous country-case sectoral studies (e.g. Dal Borgo *et al*., 2013, for the UK, Crass *et al*., 2015, for Germany; and Delbecque *et al*., 2015, for France) (see also Tables B2 and B3 in the supporting information).

[15] As can be seen from Figure B4 in the supporting information, Sweden, Finland and Denmark have the largest investment rates in innovative property, while the UK and the Netherlands have the greatest investment in economic competencies.

Figure 3 shows the average intangible composition for the market economy, the goods-producing and market services sectors and five further disaggregated sectors as introduced above. The figure shows the great sectoral heterogeneity regarding the magnitudes and composition of intangible capital investment. While the manufacturing and business services/ IC/finance sectors both have higher than average intangible investment rates, the remaining three sectors have lower than average. While the manufacturing is dominated by investments in R&D, the business services is largely dominated by investments in software and economic competencies.[16] It is interesting to note that business services/IC/finance sector also largely shape productivity patterns at the aggregate level, as argued in van Ark *et al*. (2008). Whereas the existing literature has already pointed out the higher than average intangible capital investment rates for the manufacturing sector (e.g. Corrado *et al.*, 2016; Niebel *et al.*, 2017), our results reveal that knowledge-intensive services such as business services/IC/finance sector have an equally higher than average intangible capital investment rate. This finding questions the sole emphasis given to the manufacturing sector in the literature, without elaborating upon the knowledge intensive market service sectors.

Figure 3: Business Intangible Investment Rates across Sub-Sectors



Notes: Investment rates are obtained by dividing intangible investments by total value added of sectors. Investment rates represent average values across countries and years from 1995-2017. R&D = Research and Development, OIPP = Other Intellectual Property Products, D&O = Design and Other Product Developments, A&M = Advertising, Market Research and Branding, VT = Vocational Training, POC = Purchased Organizational Capital, CI = Computerized Information, IP = Innovative Property, EC = Economic Competencies.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

[16] For detailed evidence see here also Tables B2-3 and Figure B5 in the supporting information.

6. Econometric Analysis

Following the existing literature (Roth and Thum, 2013), we estimate equation (5) by a random-effects (RE) estimation method, as reported in Table 4.[17] Estimating an EU10 cross-country sample over the time period 1995-2017 with an overall number of 207 country observations, regression (1) in Table 4 finds a statistically highly significant and positive coefficient for the elasticity of intangible capital of 0.19. The one for tangible capital is 0.22. A cross-country growth-accounting calculation shows that that intangible capital deepening explains 40 percent, tangible capital deepening explains 15 percent and TFP explains 45 percent.[18] Intangible capital deepening for the individual countries varies from 23 percent in Finland to 78 percent in Spain (see here Table B4 in the supporting information).

Table 4. Production Function Estimations for EU10 (Market Economy, 1995-2017)

	(1) Country RE	(2) Industry RE	(3) Country RE	(4) Industry RE	(5) Country RE	(6) Industry RE
Intangible Capital	0.19***	0.25***	-	-	-	-
	(2.49)	(6.89)	-	-	-	-
Tangible Capital	0.22***	0.20***	0.24***	0.20***	0.22**	0.17***
	(2.87)	(3.89)	(2.83)	(3.57)	(2.50)	(3.26)
Computerized Information	-	-	0.03**	0.05**	-	-
	-	-	(2.05)	(2.00)	-	-
Innovative Property	-	-	0.03	0.07*	-	-
	-	-	(0.70)	(1.65)	-	-
Economic Competencies	-	-	0.09***	0.13***	-	-
	-	-	(2.97)	(4.84)	-	-
Computer Software & Databases	-	-	-	-	0.02	0.05*
	-	-	-	-	(1.40)	(1.89)
Research & Development	-	-	-	-	0.04	0.02
	-	-	-	-	(1.15)	(0.86)
Design & Other Product Developments	-	-	-	-	0.01	0.15***
	-	-	-	-	(0.20)	(3.06)
Advertising, Market Research & Branding	-	-	-	-	0.05	0.01
	-	-	-	-	(1.39)	(0.36)
Organizational Capital	-	-	-	-	0.07***	0.05
	-	-	-	-	(2.84)	(1.25)
Vocational Training	-	-	-	-	-0.02	0.02
	-	-	-	-	(0.98)	(1.41)
Nelson-Phelps Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.65	0.24	0.66	0.18	0.67	0.18
Observations	207	1,897	207	1,897	207	1,897

Notes: ***p < 0.01, **p < 0.05, *p < 0.1. RE=Random Effects. Nelson-Phelps Controls and time dummies are included in every specification. *Source*: Authors' own estimations based on EU KLEMS (Stehrer *et al*., 2019).

[17] A random-effects estimator uses a GLS estimator which produces a matrix weighted average of the between and within results (a graphical illustration of the between and within variation is shown in Figure B6). To control for potential cross-sectional heteroskedasticity, a robust VCE estimator has been utilized. The Sargan-Hansen test statistic from the utilized xtoverid command is $\chi^2(6)=5.71$. This indicates that a random effects model can be used.

[18] We use a slightly revised calculation than Roth and Thum (2013). First, we perform the calculation for each of the EU10 economies individually. Second, we aggregate the values for the EU10. See here Table B4 in Appendix B in the supporting information.

Estimating the cross-country sectoral variance in regression (2), we obtain an elasticity of intangible capital of 0.25 and a slightly reduced elasticity of tangible capital of 0.20. Our results therefore suggest a greater intangible capital elasticity at the sectoral level than at the aggregate level. More importantly, an econometric growth accounting calculation suggests that intangible capital deepening accounts for up to 44 percent of labor productivity growth at the sectoral level.[19] The coefficient for intangible capital in regression (2) remains robust, when using alternative estimation approaches including a pooled panel analysis (POLS) and two-way fixed-effects (2FE), and when controlling for endogeneity by using an instrumental variable approach (2GLS) and a System Generalized Method of Moments (System-GMM) in regressions 2-5[20], excluding outliers in regressions 6-8[21] and adding control variables in regressions 9-16 in Table 6. Only when analyzing different time periods in regressions 17-19 do we detect a significant weaker impact of intangible capital on labor productivity growth, with a coefficient of 0.13 in times of crisis (2008-2013).

How do our econometric findings compare with the existing cross-country aggregate and sectoral evidence shown in Table 2? First, our results from an econometric growth accounting exercise attribute slightly lower rates to intangible capital deepening than Roth and Thum (2013) and Roth (2020). However, the magnitudes we find exceed the ones in the traditional growth accounting studies that usually attribute 25 percent of labor productivity growth to intangible capital deepening (Corrado *et al.*, 2013, 2016). Second, the sectoral elasticities we find are larger than those found by Corrado *et al*. (2016) and Niebel *et al*. (2017). More importantly, our results do not confirm previous findings by Niebel *et al*. (2017) who suggest a lower intangible capital elasticity at the sectoral level compared to the aggregate level. Third, our results clarify that in contrast to Piekkola (2018) and Adarov and Stehrer (2019), intangibles play a highly significant role in explaining labor productivity growth at the cross-country sectoral level.

To better understand the drivers behind the positive relationship between intangible capital and labor productivity growth in regressions 3-4, we differentiate in Table 4 between the three intangible dimensions: computerized information, innovative property and economic competencies. Similar to the results reported by Roth and Thum (2013) and Adarov and Stehrer (2019), we find that at the aggregate level (reg. 3), economic competencies turn out to be the dominant driver behind labor productivity growth, while innovative property is only weakly related. In contrast to the results obtained by Adarov and Stehrer (2019), we find the same result also holds for the sectoral level (reg. 4). Regressions 5-6 in Table 4 show estimation results for the six individual intangibles. While at the aggregate level we only find organizational capital to be significantly related to labor productivity growth (regression 5), at the sectoral level (regression 6) we only obtain significant results for design & other product developments and computer software and databases.

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[19] We use the calculation procedure as described in footnote 18. See here Table B5 in Appendix B in the supporting information.

[20] Both estimators utilized the first two lagged levels of tangible and intangible services growth as instruments.

[21] The outliers at hand were identified via diagnostic tests using the Stata inbuilt "avplot" command (see Figures B9-11 in the supporting information).

Table 5. Production Function Estimations for EU10 (Sectoral Level, 1995-2017)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Industry	Goods	Services	Other Goods	Manu-facturing	Distributive Services	Business Services	Other Services
	RE	RE	RE	RE	RE	RE	RE	RE
Computer Software & Databases	0.04	0.03	0.07***	0.03	0.01	0.01	0.08**	0.08***
	(0.99)	(0.93)	(2.60)	(0.72)	(0.26)	(0.57)	(2.18)	(3.35)
Research & Development	0.08***	0.13***	0.02	-0.01	0.20***	0.00	0.03	-0.01
	(3.40)	(3.27)	(1.11)	(-0.34)	(6.23)	(-0.10)	(0.97)	(-0.33)
Design & Other Product Developments	0.06	0.04	0.12**	0.20**	0.01	0.05	0.05	0.19***
	(1.20)	(0.82)	(2.18)	(2.32)	(0.19)	(0.56)	(0.47)	(3.36)
Advertising, Market Research & Branding	0.00	0.00	-0.01	-0.01	-0.01	-0.06	-0.02	0.14***
	(0.06)	(0.01)	(-0.40)	(-0.17)	(-0.11)	(-1.60)	(-0.69)	(2.65)
Organizational Capital	0.05	0.04	0.12***	0.02	0.04	0.12***	0.16***	0.05
	(1.34)	(0.92)	(4.06)	(0.51)	(0.62)	(4.53)	(2.62)	(1.16)
Vocational Training	0.03	0.03	0.03*	0.01	0.01	0.05	0.06	0.02
	(0.99)	(0.54)	(1.82)	(0.24)	(0.20)	(1.56)	(1.48)	(1.17)
Tangible Capital	0.02	0.01	0.08*	0.31**	-0.01	0.04	0.14	0.06***
	(0.19)	(0.13)	(1.87)	(3.24)	(-0.09)	(0.68)	(1.58)	(3.24)
Nelson-Phelps Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.09	0.09	0.24	0.23	0.11	0.32	0.24	0.49
Observations	3,834	2,765	1,069	621	2,144	351	516	202

Notes: ***p < 0.01, **p < 0.05, *p < 0.1. RE = random effects regression. Nelson-Phelps Controls and time dummies are included in every specification.
Source: Authors' own estimations based on EU KLEMS (Stehrer *et al*., 2019).

Given the disappointing results from regressions 5-6 in Table 4, we estimate the six individual intangibles at further disaggregated sectors of the economy in Table 5. To benefit from sectoral variation, we decided to include 3-digit manufacturing industries in our analysis, which increases our total number of observations from 1,897 to 3,834. We first analyze all sectors in regression 1. We then differentiate the goods and the market services in regressions 2-3[22], and we differentiate among our five sub-sectors in regressions 4-8.

When analyzing all sectors (reg. 1), we now observe that R&D is the only type of intangible capital with both a statistically significant and positive effect on labor productivity growth. When we take a step further and differentiate between the goods and services sectors (reg. 2-3), we observe that while research and development is the only intangible capital with a statistically significant coefficient in the goods sector, individual intangibles, including computer software and databases, design and other product developments, organizational capital and vocational training, have significant elasticities for the market services.

The results in regressions 4-8 of Table 5 for our five disaggregated sectors confirm the heterogeneous character of sectors regarding the use of intangibles. While design and other product developments is the dominant type of intangible found in the Other Goods sector, it is research and development in Manufacturing. On the other hand, we see that organizational capital impacts labor productivity growth most strongly in the Distributive- and Business Services sub-sectors. While computer software and databases exerts considerable effects on labor productivity growth in the Business- and Other Services sub-sectors, it is design and other product developments and advertising, market research and branding that are the most influential intangibles for Other Services. Overall, the results in Table 5 confirm our descriptive analysis in section 5, where we see that research and development investments dominate intangible investment in the goods sector, and organizational capital and computer software and databases dominate intangible investment in the market services sectors.

How should we interpret our results from Table 5 in the light of the existing literature? Our results show that investment in organizational capital, software and vocational training exerts a strong impact on labor productivity growth in the services sectors. We relate this phenomenon to the Brynjolfsson *et al*. (2002) argument which states that the firms need complementary investments in organizational change and training to fully reap the benefits of innovations in information technologies. Considering the fact that the Distributive Services and Business Services sub-sectors largely account for aggregate productivity (van Ark *et al*., 2008), we believe that our strong findings on the effects of organizational capital in these sectors demonstrate the importance of this type of intangible for market services and the aggregate economy.

[22] See Figures B7-8 for graphical illustrations of the between and within variation in the goods and market services sector.

Table 6. Robustness Checks

	IC Coeff.	SE	Observations
(1) Benchmark	0.25***	(6.89)	1,897
Alternative Estimation Methods			
(2) POLS	0.26***	(9.07)	1,897
(3) 2FE	0.25***	(6.28)	1,897
(4) 2GLS	0.24***	(3.70)	1,897
(5) System-GMM	0.22**	(2.60)	1,897
Country/Sector Exclusions/Inclusions			
(6) EU10 (Excluding Sweden and Sector J)	0.24***	(5.35)	1,877
(7) EU10 (Excluding Sweden)	0.27***	(4.71)	1,677
(8) EU10 (Including NMS)	0.27***	(4.58)	2,661
Control Variables			
(9) Rule of Law	0.23***	(6.63)	1,475
(10) FDI (% of GDP)	0.24***	(6.25)	1,605
(11) Government Expenditures (% of GDP)	0.25***	(7.27)	1,741
(12) Social Expenditures ((% of GDP)	0.25***	(7.18)	1,741
(13) Education Expenditures (% of GDP)	0.26***	(7.18)	1,667
(14) Inflation (in %)	0.25***	(7.14)	1,741
(15) Income Tax (% of GDP)	0.25***	(7.16)	1,741
(16) Stock Market Capitalization (% of GDP)	0.26***	(3.91)	1,301
Across Different Time Periods			
(17) EU10 (Before 2008)	0.28***	(4.11)	980
(18) EU10 (Between 2008 and 2013)	0.13**	(2.16)	572
(19) EU10 (After 2013)	0.26***	(6.63)	345

Notes: ***p < 0.01, **p < 0.05, *p < 0.1. Results refer to the random effects estimator. SE=Standard Error. IC=Intangible Capital, Coeff.=Coefficient, NMS=New member States. Nelson-Phelps Controls and time dummies are included in every specification.
Source: Authors' own estimations based on EU KLEMS (Stehrer *et al*., 2019).

7. Conclusion and Outlook

In this paper we study the determinants of labor productivity growth employing a growth econometric estimation approach across countries and sectors using the harmonized EU KLEMS 2019 dataset. Analyzing intangibles and the market economy at different aggregation levels for the EU10 over the period 1995-2017, our analysis has produced three novel results.

First, our aggregate and sectoral results suggest that intangibles play a prominent role in labor productivity growth. Intangible capital deepening accounts for around 40 percent of labor productivity growth at both the aggregate and sectoral levels. In contrast to the existing studies in the literature, we find that intangible capital has a greater elasticity at the sectoral level than at the aggregate level. Second, when we differentiate between three intangible capital dimensions, we observe that the impact of intangible capital on labor productivity growth at the aggregate and sectoral levels is largely driven by economic competencies. Considering the fact that this type of intangibles is not included in the National Accounts, we argue that recognition of this fact would lead to a better assessment of the effects of intangible capital investment on productivity.

Third, our disaggregated analysis points towards a deep sectoral heterogeneity in the use of intangible capital. While R&D dominates intangible capital investments in the goods sector, it is software and organizational capital that drive intangible capital investments in market services. Furthermore, certain intangibles such as software, vocational training, and organizational capital influence productivity growth more strongly in market services sector than the goods sector. Considering that market services also account for the productivity gap between the EU and the US (van Ark *et al*., 2008), we argue that our results suggest that intangibles, and especially organizational capital, could play a critical role in explaining and closing this gap. We therefore conclude that our disaggregated analysis complements our econometric evidence and demonstrates the importance of intangible capital investment in aggregate productivity.

We think that our results on intangible capital in the services sector have important policy implications. More specifically, we think that the success of the EU countries in catching up to the US level of productivity in the manufacturing sector and their lagging behind in market services could be related to the different composition of intangibles in these sectors. It appears that while R&D is highly consequential for manufacturing, a different set of intangibles (software, vocational training, and organizational capital) shapes productivity within the services sectors. The lack of the EU's success in improving its productivity growth in services could be related to the fact that its industrial policy concentrates too much on R&D, which is less relevant for services. We believe that acknowledging this fact as a reality could open up new avenues for policy discussions following the Europe 2020 strategy.

Considering the importance of organizational capital for productivity in the market services sector, we believe that future research should focus on understanding the drivers of organizational capital investments across countries and how this intangible type of investment shapes productivity in this sector. Although Bloom and van Reenen (2007) discuss management differences across countries, future research should focus on quantifying how these differences translate into organizational capital and productivity growth in the market services sector.

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Supplementary Information

Appendix A. Summary Statistics

Appendix B. Additional Descriptive Tables and Figures

Appendix C. List of Countries, Intangibles, and Sectors

Appendix D. Construction of Capital Services Growth

Appendix A. Summary Statistics

Table A1. Summary Statistics (Country Level)

	Mean	Median	Min	Max	Standard Deviation	Number of Observations
Labor Productivity Growth	0.02	0.02	-0.07	0.07	0.02	207
Intangible Capital per Labor Services Growth	0.03	0.03	-0.02	0.14	0.02	207
Tangible Capital per Labor Services Growth	0.01	0.01	-0.05	0.11	0.02	207
Upper secondary Education	67.84	71.60	37.00	82.30	10.97	207
Catchup Term	55.31	53.45	21.26	93.79	15.74	207
Business Cycles	0.92	0.92	0.74	0.97	0.04	207

Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*. 2019). Upper secondary education and business cycles data (unemployment rate) are obtained from Eurostat.

Table A2. Summary Statistics (Sectoral Level)

	Mean	Median	Min	Max	Standard Deviation	Number of Observations
Labor Productivity Growth	0.01	0.01	-0.23	0.3	0.05	1,897
Intangible Capital per Labor Services Growth	0.03	0.03	-0.2	0.91	0.05	1,897
Tangible Capital per Labor Services Growth	0.01	0.01	-0.22	0.35	0.05	1,897
Upper-Secondary Education	67.53	71.6	37	82.3	11.19	1,897
Catchup Term	55.12	53.85	21.26	93.79	15.86	1,897
Business Cycles	0.92	0.93	0.74	0.97	0.04	1,897
Innovative Property per Labor Services Growth	0.02	0.02	-1.69	0.85	0.08	1,897
Economic Competencies per Labor Services Growth	0.02	0.02	-0.27	0.65	0.06	1,897
Computer Software & D. per Labor Services Growth	0.05	0.04	-0.58	1.25	0.1	1,897
Research & Development per Labor Services Growth	0.03	0.02	-0.4	1.26	0.12	1,897
Design & O. Product Dev. per Labor Services Growth	0.03	0.02	-0.18	0.4	0.05	1,897
Advertising & Market Res. per Labor Services Growth	0.02	0.02	-0.5	1	0.07	1,897
Organizational Capital per Labor Services Growth	0.03	0.03	-0.3	1.01	0.07	1,897
Vocational Training per Labor Services Growth	0.01	0.01	-0.56	0.42	0.06	1,897
Rule of Law	1.59	1.78	0.28	2.1	0.47	1,475
Foreign Direct Investment (% of GDP)	1.53	1.4	-9.6	10.2	4.23	1,605
Government Expenditures (% of GDP)	48.23	48.3	35.3	59.2	5.53	1,741
Social Expenditures (% of GDP)	24.23	25.1	15.5	32	3.82	1,741
Education Expenditures (% of GDP)	5.66	5.5	4.08	8.81	1.16	1,667
Inflation Rate	1.53	1.5	-0.63	4	0.86	1,741
Income Tax	10.99	9.53	5.36	26.35	4.9	1,741
Stock Market Capitalization (% of GDP)	73.41	65.77	1.19	258.38	42.05	1,301

Source: Authors' own estimations based on the EU KLEMS data set (Stehrer *et al*., 2019). Upper secondary education and business cycles data (unemployment rate), government expenditures and the inflation rate are obtained from Eurostat. Rule of law, FDI, social expenditures, education expenditures, and stock market capitalization are obtained from the World Bank.

Appendix B. Additional Descriptive Tables and Figures

Table B1. Aggregate and Sectoral Labor Productivity Growth Rates for EU10 and the US

		Market Economy	Goods	Market Services	Manufacturing	Wholesale and Retail Trade	Transportation and Storage	Information and Communication	Finance	Business Services
EU10	1995-2007	2.18	2.66	1.71	3.92	2.35	1.85	4.35	3.38	-0.31
	2008-2013	0.54	0.83	0.43	1.58	0.81	0.92	2.34	1.06	-0.24
	2014-2017	1.28	1.65	0.82	1.67	2.29	-0.64	2.87	0.39	0.42
Austria	1995-2007	2.52	3.46	1.74	3.88	1.66	1.80	2.48	5.08	0.15
	2008-2013	0.67	0.90	0.47	1.27	0.69	0.59	-1.04	2.07	0.42
	2014-2017	1.31	2.68	0.42	2.65	0.67	0.14	0.86	3.58	0.39
Denmark	1995-2007	1.89	3.08	1.76	2.70	2.19	1.65	6.00	5.05	-2.17
	2008-2013	1.40	0.77	0.78	5.41	1.61	3.44	4.97	-1.58	-0.55
	2014-2017	0.84	2.53	0.35	0.90	2.02	-1.27	4.43	-4.36	1.39
Finland	1995-2007	3.60	5.02	2.05	6.55	3.51	0.92	5.02	2.21	-0.05
	2008-2013	-0.54	-0.72	-0.05	-1.86	-0.35	2.30	3.78	-2.46	-1.29
	2014-2017	2.12	2.99	1.35	3.96	2.70	-0.22	0.98	1.02	1.11
France	1995-2007	2.11	2.38	1.54	4.00	1.51	2.51	4.19	2.05	-0.28
	2008-2013	0.42	0.46	0.25	2.60	-0.25	1.59	1.16	2.45	-0.78
	2014-2017	1.05	1.75	0.74	2.28	2.09	-0.13	2.20	-2.41	0.03
Germany	1995-2007	2.11	2.07	1.37	3.44	3.21	3.67	4.52	-1.05	-1.82
	2008-2013	0.47	2.65	0.18	0.93	0.19	0.41	3.89	2.00	-1.89
	2014-2017	1.46	1.71	0.71	2.79	2.31	-0.81	0.76	0.97	-0.48
Italy	1995-2007	0.70	0.81	0.52	1.13	0.79	1.53	3.45	1.63	-2.66
	2008-2013	0.08	0.75	-0.42	1.57	-0.30	-0.65	0.72	2.61	-1.81
	2014-2017	0.40	0.83	0.10	1.97	1.84	-0.83	0.31	0.88	-0.77
Netherlands	1995-2007	2.24	2.37	2.29	3.87	3.19	2.81	4.71	2.95	0.65
	2008-2013	0.39	0.58	0.39	1.00	1.83	1.34	0.63	1.37	-0.61
	2014-2017	0.59	1.46	0.29	2.02	2.05	-0.99	1.50	3.21	-0.45
Spain	1995-2007	0.03	0.32	-0.23	1.61	0.25	-0.53	0.75	6.76	-2.90
	2008-2013	1.89	3.85	1.12	2.66	2.00	2.37	2.33	-2.66	0.99
	2014-2017	1.03	0.48	0.36	0.76	2.53	1.45	0.22	-1.58	1.62
Sweden	1995-2007	3.82	4.80	3.03	6.26	4.26	1.87	4.24	3.48	2.05
	2008-2013	1.02	0.09	1.72	2.28	2.07	1.64	3.43	4.95	1.35
	2014-2017	3.02	1.39	3.51	1.04	2.62	1.11	8.19	3.79	1.02
UK	1995-2007	2.75	2.33	2.99	3.63	1.88	3.40	4.59	5.85	2.61
	2008-2013	-0.40	-1.03	-0.13	0.08	0.55	-1.54	-0.36	-1.45	1.17
	2014-2016	0.45	0.66	0.39	0.04	4.46	-4.75	4.13	0.53	-0.03
US	1995-2007	2.86	3.33	2.66	6.07	3.40	0.73	7.91	3.13	1.00
	2008-2013	1.42	1.90	1.28	1.41	0.83	-1.38	6.25	4.34	0.35
	2014-2017	1.00	0.24	1.35	-0.07	1.85	-0.74	7.94	-1.37	0.76

Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Table B2. Sectoral Intangible Investment Rates

	Austria	Germany	Denmark	Spain	Finland	France	Italy	Netherlands	Sweden	UK	US	Average
Agriculture	0.01	0.02	0.04	0.00	0.00	0.02	0.01	0.03	0.02	0.01	0.00	0.02
Mining	0.06	0.09	0.05	0.04	0.17	0.19	0.07	0.05	0.09	0.06	0.05	0.08
Manufacturing	0.11	0.12	0.14	0.06	0.18	0.18	0.10	0.12	0.19	0.10	0.14	0.13
Electricity and Gas	0.04	0.04	0.03	0.01	0.06	0.08	0.04	0.11	0.05	0.05	0.04	0.05
Water Supply	0.02	0.07	0.12	0.02	0.04	0.06	0.08	0.06	0.12	0.05	0.04	0.06
Construction	0.05	0.02	0.13	0.04	0.07	0.06	0.05	0.07	0.13	0.05	0.03	0.06
Wholesale and Retail Trade	0.06	0.03	0.06	0.04	0.09	0.05	0.07	0.09	0.07	0.07	0.07	0.06
Transportation and Storage	0.03	0.02	0.04	0.03	0.05	0.04	0.03	0.06	0.05	0.07	0.03	0.04
Food and Accommodation	0.01	0.01	0.03	0.01	0.06	0.03	0.03	0.05	0.03	0.05	0.06	0.03
Information and Communication	0.15	0.11	0.20	0.13	0.16	0.20	0.20	0.12	0.21	0.19	0.19	0.17
Finance	0.12	0.05	0.08	0.07	0.09	0.10	0.05	0.11	0.13	0.12	0.08	0.09
Business Services	0.13	0.07	0.12	0.12	0.17	0.17	0.09	0.14	0.20	0.15	0.11	0.14
Arts & Entertainment	0.10	0.05	0.15	0.02	0.06	0.04	0.14	0.11	0.11	0.09	0.10	0.09
Other Services	0.04	0.01	0.05	0.02	0.03	0.05	0.05	0.09	0.05	0.08	0.05	0.05
Market Economy	0.08	0.07	0.10	0.05	0.12	0.11	0.07	0.10	0.14	0.10	0.09	0.09
Goods	0.08	0.10	0.11	0.04	0.13	0.12	0.08	0.09	0.16	0.08	0.11	0.10
Market Services	0.08	0.05	0.09	0.06	0.11	0.11	0.08	0.11	0.12	0.11	0.10	0.09
Other Goods	0.04	0.03	0.08	0.03	0.06	0.06	0.04	0.06	0.09	0.05	0.03	0.05
Manufacturing	0.11	0.12	0.14	0.06	0.18	0.18	0.10	0.12	0.19	0.10	0.16	0.13
Distributive Services	0.05	0.03	0.05	0.04	0.08	0.05	0.06	0.08	0.06	0.07	0.07	0.06
Business Services/IC/Finance	0.13	0.08	0.13	0.11	0.15	0.17	0.10	0.13	0.19	0.15	0.13	0.13
Other Services	0.03	0.02	0.08	0.01	0.05	0.04	0.05	0.08	0.06	0.07	0.07	0.05

Notes: Intangible investment rates are obtained by dividing total intangible investments by value added.
Source: Authors' own estimations based on the EU KLEMS data set (Stehrer *et al.*, 2019).

Table B3. Sectoral Contributions to Aggregate Intangible Investment Rate

	Austria	Germany	Denmark	Spain	Finland	France	Italy	Netherlands	Sweden	UK	US	Average
Agriculture	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.02	0.01	0.01
Manufacturing	0.35	0.54	0.29	0.24	0.48	0.32	0.32	0.22	0.39	0.17	0.31	0.33
Electricity & Gas	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01
Water Supply	0.00	0.02	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01
Construction	0.05	0.02	0.11	0.09	0.06	0.04	0.05	0.05	0.08	0.04	0.02	0.06
Wholesale and Retail Trade	0.14	0.07	0.12	0.13	0.11	0.07	0.15	0.15	0.08	0.12	0.12	0.11
Transportation and Storage	0.03	0.02	0.03	0.03	0.03	0.02	0.03	0.04	0.03	0.04	0.02	0.03
Food and Accommodation	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.02	0.03	0.01
Information and Communication	0.09	0.09	0.13	0.15	0.10	0.13	0.16	0.08	0.12	0.17	0.19	0.13
Finance	0.09	0.05	0.06	0.09	0.03	0.05	0.04	0.11	0.05	0.13	0.09	0.07
Business Services	0.18	0.15	0.15	0.23	0.15	0.30	0.16	0.26	0.20	0.24	0.17	0.20
Arts & Entertainment	0.02	0.01	0.04	0.01	0.01	0.01	0.03	0.02	0.01	0.02	0.02	0.02
Other Services	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01
Other Goods	0.08	0.06	0.15	0.11	0.08	0.08	0.08	0.10	0.11	0.08	0.04	0.09
Manufacturing	0.35	0.54	0.29	0.24	0.48	0.32	0.32	0.22	0.39	0.17	0.31	0.33
Distributive Services	0.16	0.09	0.15	0.16	0.14	0.09	0.18	0.19	0.10	0.16	0.14	0.14
Business Services/IC/Finance	0.36	0.29	0.34	0.46	0.28	0.48	0.36	0.45	0.37	0.53	0.45	0.40
Other Services	0.04	0.02	0.05	0.03	0.02	0.03	0.06	0.04	0.03	0.06	0.06	0.04

Notes: Sectoral contributions to aggregate intangible investment rate are obtained by dividing intangible investment in a sector by intangible investments in all sectors.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Table B4. Growth Accounting at the Country Level

	Intangible Capital Contribution	**Tangible Capital Contribution**	**TFP Contribution**	**Labor Productivity Growth**
Austria	0.94	0.23	0.52	1.69
	55.51	13.74	30.75	
Denmark	0.80	0.08	0.48	1.36
	58.73	5.91	35.36	
Finland	0.48	-0.02	1.61	2.07
	23.10	-0.92	77.83	
France	0.53	0.25	0.58	1.37
	38.99	18.54	42.47	
Germany	0.54	0.15	0.81	1.51
	36.15	10.23	53.62	
Italy	0.21	0.15	0.08	0.44
	48.14	34.18	17.68	
Netherlands	0.67	0.17	0.57	1.41
	47.77	11.77	40.46	
Spain	0.47	0.36	-0.22	0.61
	77.59	58.75	-36.34	
Sweden	0.72	0.43	1.34	2.49
	28.89	17.33	53.78	
UK	0.42	0.36	0.67	1.45
	28.87	24.89	46.25	
Average	0.58	0.22	0.64	1.44
	40.21	15.06	44.73	

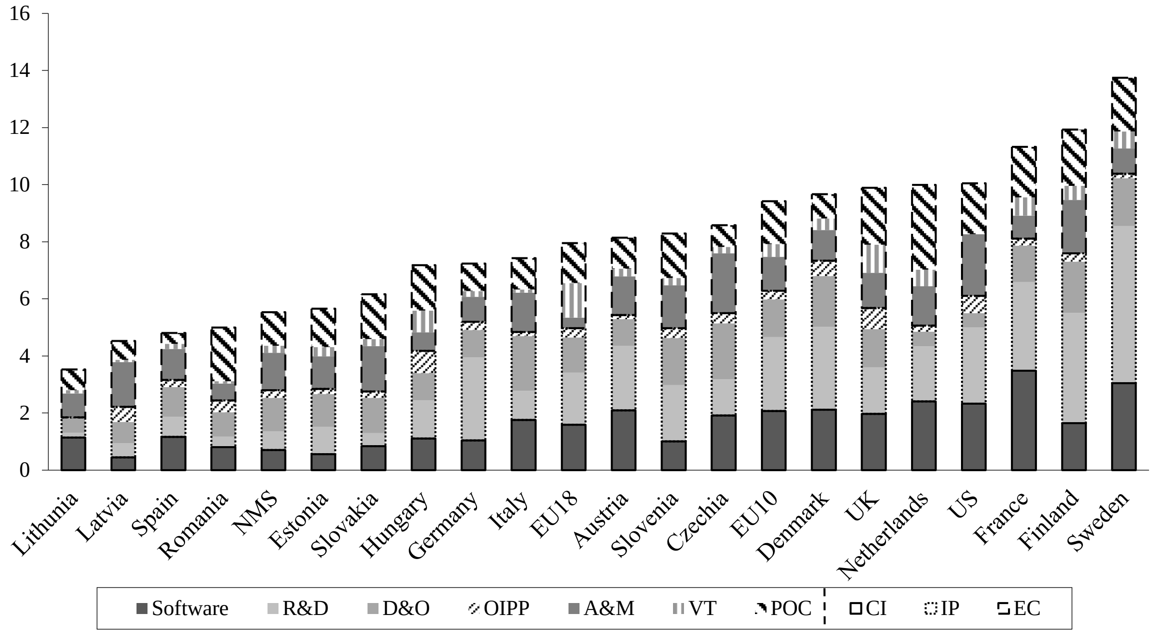
Source: Authors' own estimations based on econometric results and the EU KLEMS dataset (Stehrer *et al*., 2019).

Table B5. Growth Accounting at the Industry Level

	Intangible Capital Contribution	**Tangible Capital Contribution**	**TFP Contribution**	**Labor Productivity Growth**
Austria	1.06	0.16	0.45	1.67
	63.52	9.58	26.89	
Denmark	0.6	0.11	0.76	1.47
	59.85	5.88	34.27	
Finland	0.53	-0.03	1.56	2.05
	25.69	-1.49	75.8	
France	0.49	0.15	0.71	1.35
	36.2	11.23	52.57	
Germany	0.6	0.11	0.76	1.47
	41.2	7.25	51.55	
Italy	0.25	0.14	0.04	0.43
	57.64	32.25	10.11	
Netherlands	0.73	0.09	0.58	1.4
	51.8	6.62	41.59	
Spain	0.58	0.3	-0.28	0.6
	97.1	50.32	-47.42	
Sweden	0.8	0.34	1.33	2.46
	32.36	13.62	54.02	
UK	0.47	0.33	0.61	1.42
	33.24	23.38	43.38	
Average	0.63	0.17	0.61	1.41
	44.43	11.73	43.84	

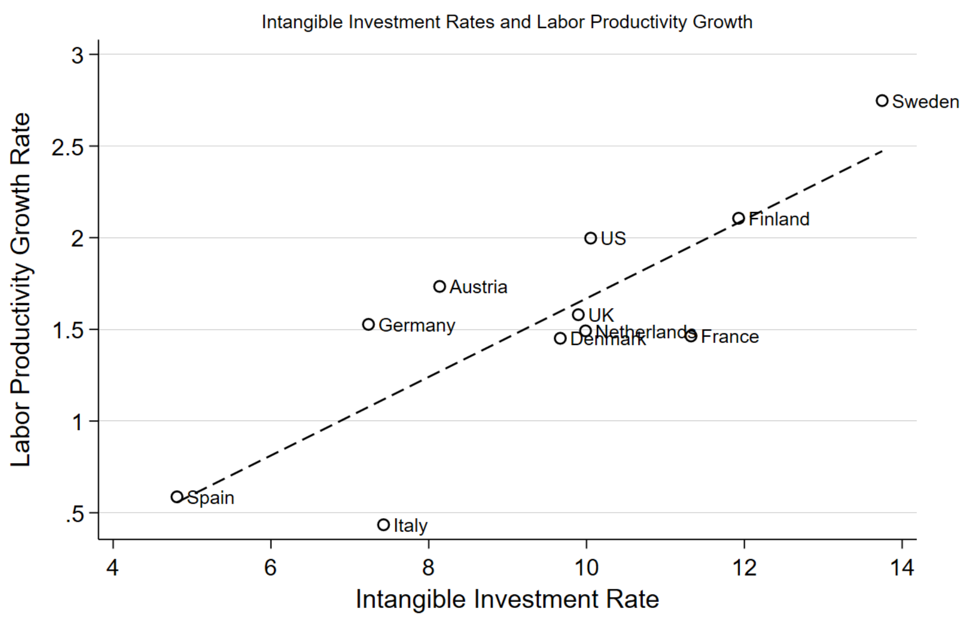
Source: Authors' own estimations based on econometric results and the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B1. Business Intangible Capital Investment (as a percent. of VA), EU18, 1995-2017



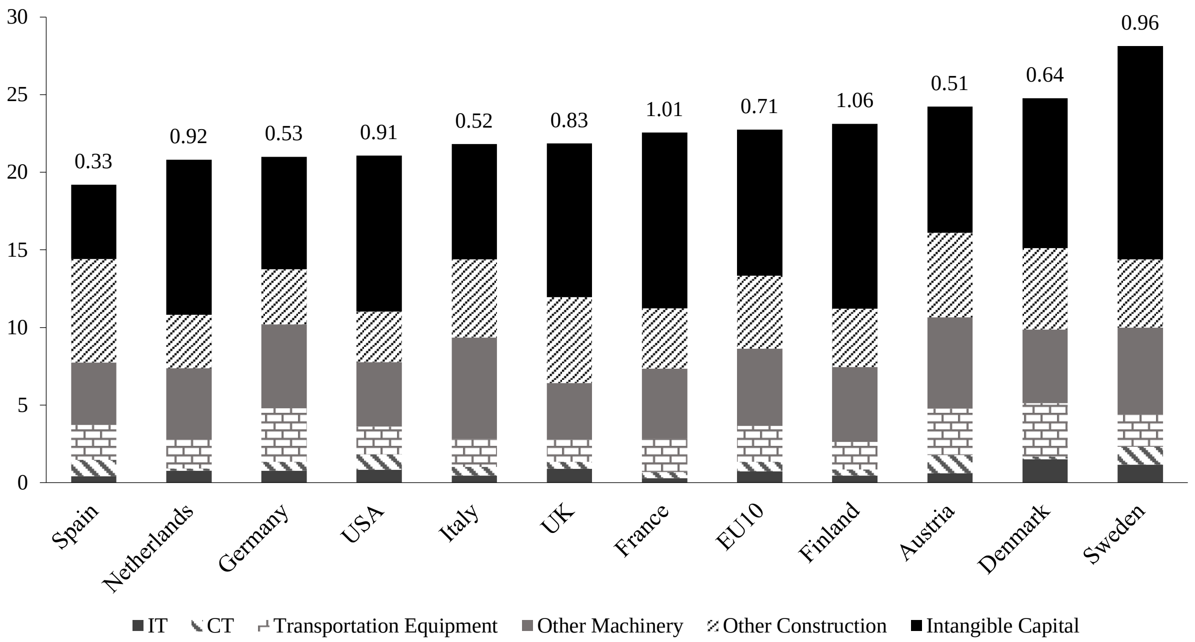
Notes: Investment rates are obtained by dividing intangible investments by total value added in the business sector excluding real estate. Investment rates represent time averages for each country. R&D = Research and Development, OIPP = Other Intellectual Property Products, D&O = Design and Other Product Developments, A&M = Advertising, Market Research and Branding, VT = Vocational Training, POC = Purchased Organizational Capital, CI = Computerized Information, IP = Innovative Property, EC = Economic Competencies.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al.*, 2019).

Figure B2. Intangible Investment Rates and Labor Productivity Growth across Countries



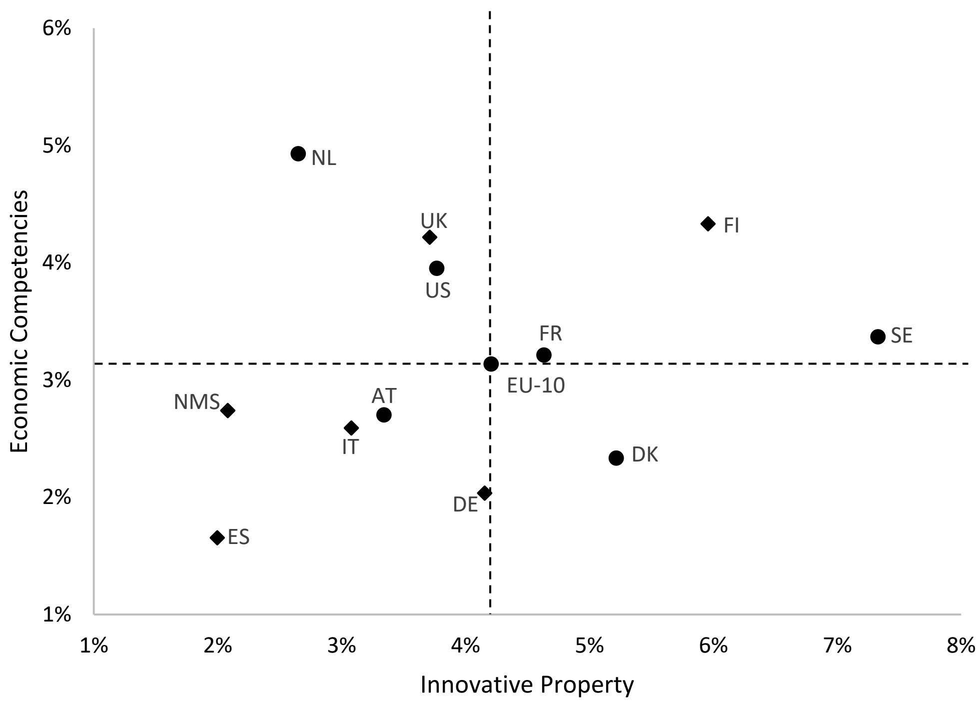
Notes: Intangible investment and labor productivity growth rates are average values from 1995 to 2017.
Source: Authors' own estimations based on the EU KLEMS dataset(Stehrer *et al.*, 2019).

Figure B3. Tangible and Intangible Investment Rates in the Market Economy, EU10 and US



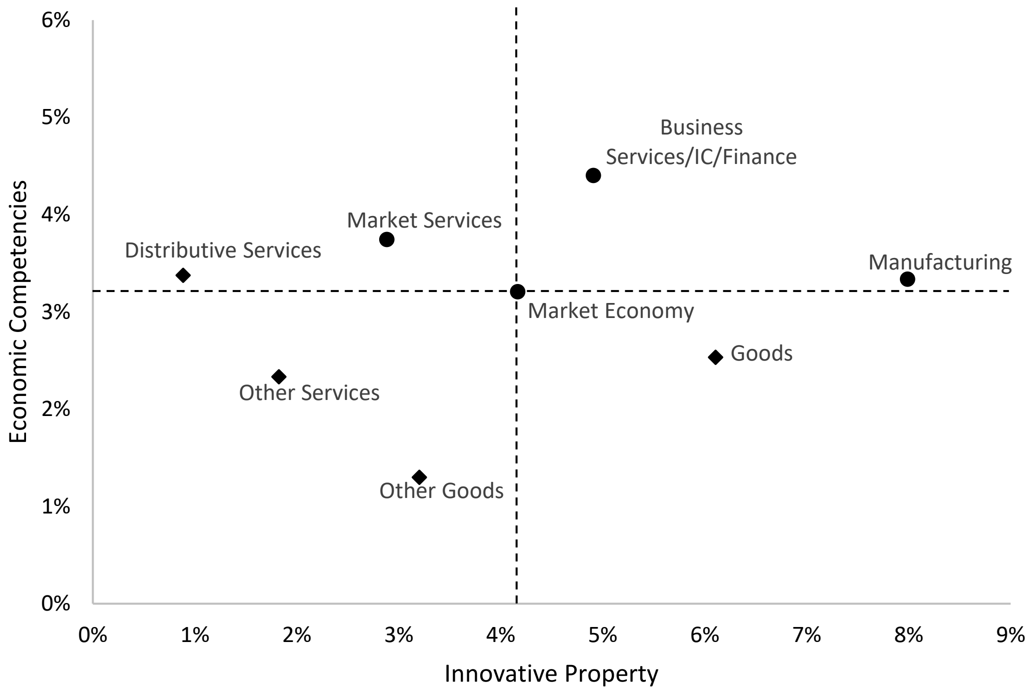
Notes: Investment rates are obtained by dividing tangible and intangible investments by total value added in the business sector excluding real estate. Investment rates represent time averages for each country. The numbers above the bars in the chart show the ratio of intangible investments over tangible ones.
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B4. Investment Rates in Economic Competencies vs. Innovative Property across Countries



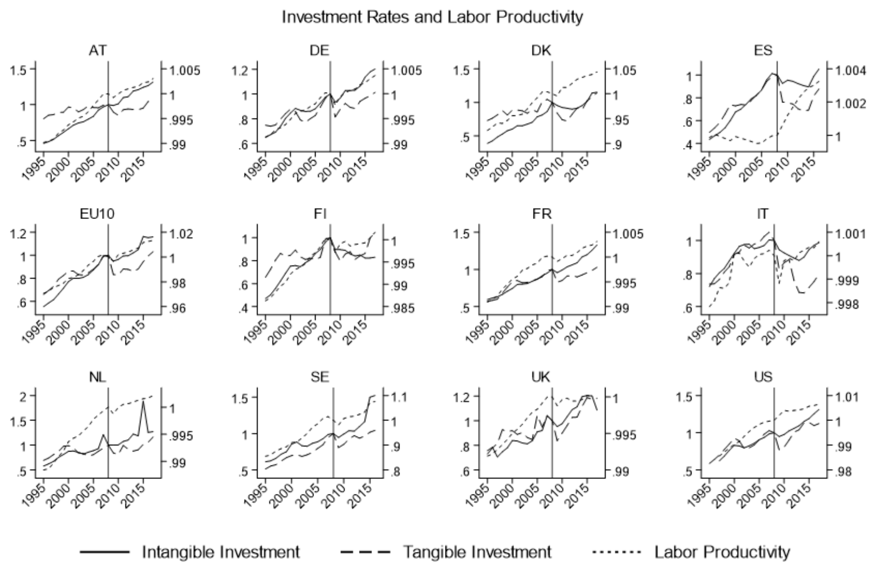
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019)

Figure B5. Investment Rates in Economic Competencies vs. Innovative Property across Sectors



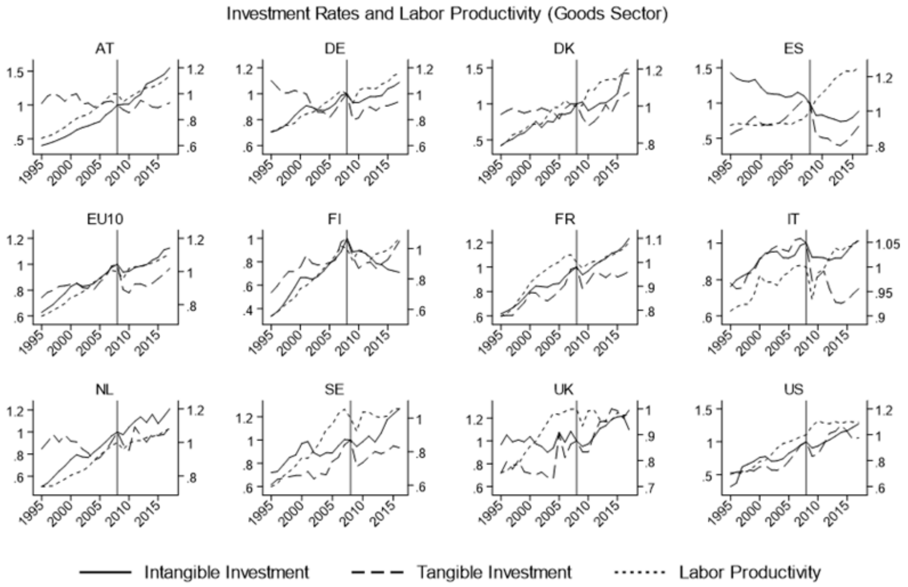
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B6. Tangible/Intangible Investment Rates and Labor Productivity Growth



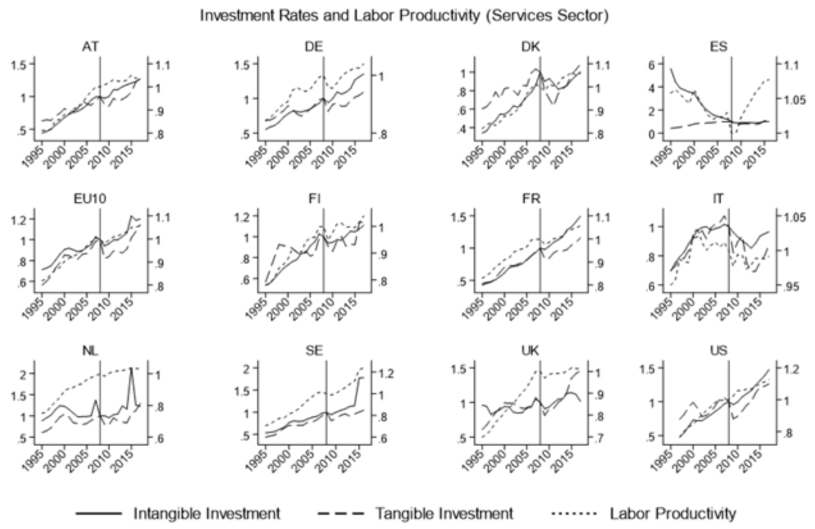
Notes: For all countries, values are normalized to 1 in year 2008.
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B7. Tangible/Intangible Investment Rates and Labor Productivity Growth (Goods Sector)



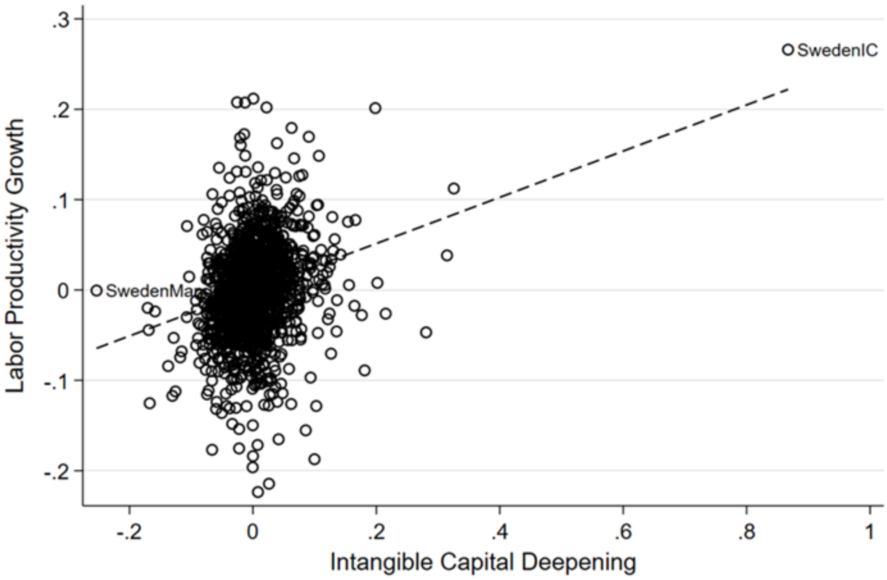
Notes: For all countries, values are normalized to 1 in year 2008.
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B8. Tangible/Intangible Investment Rates and Labor Productivity Growth (Services Sector)



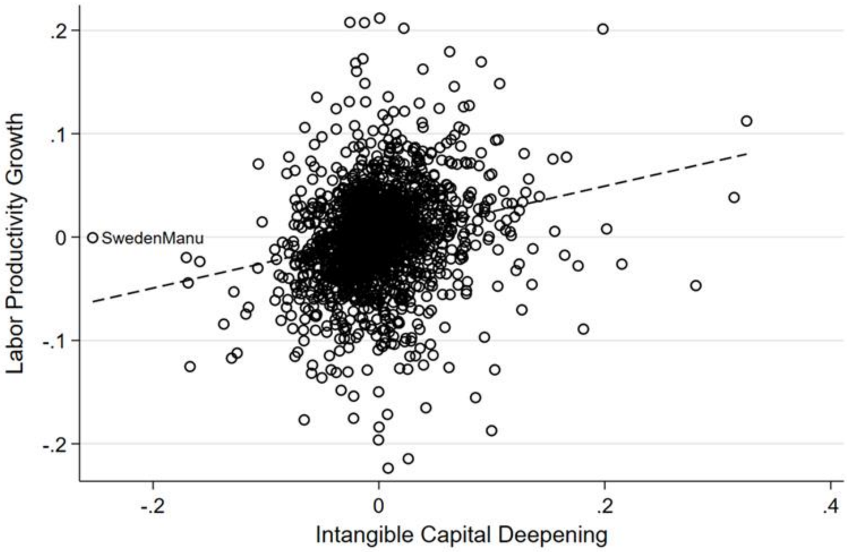
Notes: For all countries, values are normalized to 1 in year 2008.
Source: Authors' own estimation based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B9. Diagnostic Tests



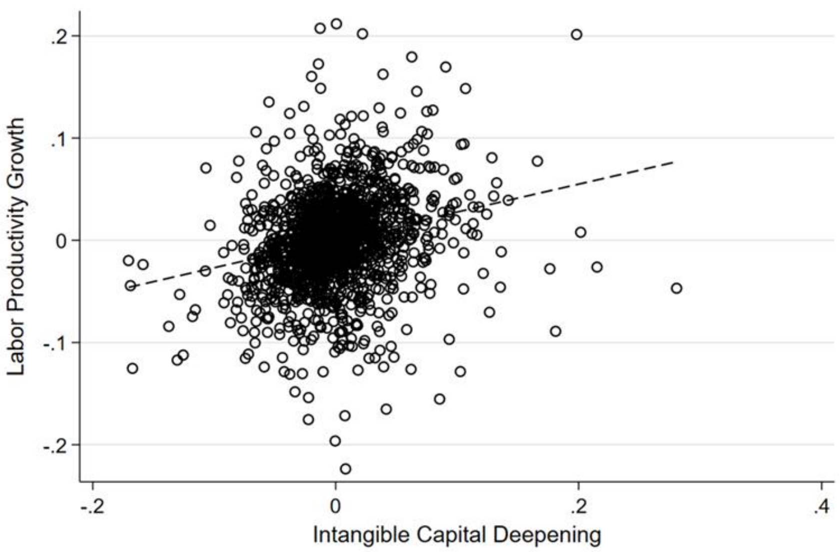
Notes: "Avplot" command on STATA is used to derive the graphs.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B10. Diagnostic Tests (after excluding sector J in Sweden)



Notes: "Avplot" command on STATA is used to derive the graphs.
Source: Authors own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Figure B11. Diagnostic Tests (after excluding Sweden)



Notes: "Avplot" command on STATA is used to derive the graphs.
Source: Authors' own estimations based on the EU KLEMS dataset (Stehrer *et al*., 2019).

Appendix C. List of Countries, Intangibles, and Sectors

Table C1. Chronological Timeframe of Datasets Measuring Intangibles

Databases	Period	Countries	Variables	Level	Economic Sector	Relevant Studies on Intangibles and LPG
EU KLEMS						
O'Mahony and Timmer (2009)	1970-2015	EU-28, US	Tangibles and National Accounts intangibles	Meso	Business	Van Ark *et al.* (2008)
INNODRIVE						
Jona-Lasinio *et al.* (2011)	1995-2005	EU-27, NO	Expanded framework intangibles and adjusted productivity measures	Macro	Business	Roth and Thum (2013)
INTAN-Invest, Revision I						
Corrado *et al.* (2013)	1995-2015	US, AT, BE, CZ, DE, DK, FI, FR, EL, ES, HU, IE, IT, LU, NL, PT, SK, SI, SE, UK	Expanded framework intangibles, and adjusted productivity measures	Macro	Business	Corrado *et al.* (2013)
INDICSER						
Niebel *et al*. (2017)	1995-2007	AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, IT, NL, SE, UK	Expanded framework intangibles, and adjusted productivity measures	Meso	Business	Niebel *et al*. (2017); Chen *et al*. (2016)
SPINTAN						
Corrado *et al*. (2017b)	2000-2012	US, AT, BE, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IE, IT, LU, NL, NO, PL, PT, SK, SE, UK	Public sector intangibles	Macro	Public	Corrado *et al*. (2017b)
INTAN-Invest, Revision II						
Corrado *et al.* (2018)	1995-2015	US, AT, BE, CZ, DE, DK, FI, FR, EL, ES, HU, IE, IT, NL, PT, SK, SI, SE, UK	Expanded framework intangibles, and adjusted productivity measures	Meso	Business	Corrado *et al*. (2018); Roth (2020)
EU KLEMS (Statistical + Analytical Database)						
Stehrer *et al*. (2019)	1995-2017	EU-28, JP, US	Tangibles, National Accounts, and expanded framework intangibles adjusted productivity statistics	Meso	Whole economy	Stehrer *et al*. (2019)

Source: Authors' own compilation based on the information derived from the references cited in the table.

Table C2. Intangible Capital Availability at the Sectoral Level

States	**Intangible Capital Information Available at the Sectoral Level**
EU15	
Austria	Yes
Belgium	No
Denmark	Yes
Finland	Yes
France	Yes
Germany	Yes
Greece	No
Ireland	No
Italy	Yes
Luxembourg	Yes
Netherlands	No
Portugal	No
Spain	Yes
Sweden	Yes
UK	Yes
New Member States	
Bulgaria	No
Croatia	No
Cyprus	No
Czech Republic	Yes
Estonia	Yes
Hungary	Yes
Latvia	Yes
Lithunia	Yes
Malta	No*
Poland	No
Romania	Yes
Slovakia	Yes
Slovenia	Yes
Non-EU	
US	Yes

Notes: * Real value only available for one time period.
Source: List of countries and the availability of information on intangible capital are taken from the EU KLEMS dataset (Stehrer *et al*., 2019).

Table C3. List of Sectors and NACE Codes

Sectors	**NACE Code**
Goods	
Agriculture	A
Mining	B
Manufacturing	C
Electricity and Gas	D
Water Supply	E
Construction	F
Services	
Wholesale and Retail Trade	G
Transportation and Storage	H
Food and Accommodation	I
Information and Communication	J
Finance	K
Business Services	M-N
Arts & Entertainment	R
Other Services	S

Source: Sectoral names and their NACE codes are taken from the EU KLEMS dataset (Stehrer *et al*., 2019).

Table C4. Sectoral Classifications and NACE Codes

Sectors	**NACE Code**
Other Goods	
Agriculture	A
Mining	B
Electricity and Gas	D
Water Supply	E
Construction	F
Manufacturing	
Manufacturing	C
Distributive Services	
Wholesale and Retail Trade	G
Transportation and Storage	H
Business Services/IC/Finance	
Information and Communication	J
Finance	K
Business Services	M-N
Other Services	
Food and Accommodation	I
Arts&Entertainment	R
Other Services	S

Source: Sectoral classifications and NACE codes are taken from the EU KLEMS database (Stehrer *et al*., 2019).

Table C5. Types of Capital

	Acronym
Tangible Capital	
Computing Equipment	IT
Communications Equipment	CT
Transport Equipment	TraEq
Other Machinery and Equipment	Omach
Total Non-Residential Investment	Ocon
Intangible Capital	
Computer Software and Databases	Software
Research and Development	R&D
Other IPP Assets	OIPP
Advertising, Market Research and Branding	A&M
Design and Other Product Developments	D&O
Purchased Organizational Capital	POC
Vocational Training	VT

Source: Variable names and acronyms are taken from the EU KLEMS dataset (Stehrer *et al*.. 2019).

Appendix D. Construction of Capital Services Growth

Because our analysis includes types of intangible capital that are not considered in the National Accounts (such as advertising, market research and branding, design and other product developments, organizational capital, and vocational training), we first have to adjust sectoral nominal value added as follows:

[D.1] $$VA_{adj,j,t} = VA_{j,t} + \sum_{k \epsilon INT} I_{k,j,t}$$

We also have to define a new value-added price deflator to adjust for these new intangibles:

[D.2] $$\Delta lnVAP_{adj,j,t} = \bar{v}_{VA,j,t} \Delta lnVAP_{j,t} + \bar{v}_{INT,j,t} \Delta lnIPINT_{j,t}$$

where $\bar{v}_{VA,j,t}$ represents the average share of the unadjusted nominal value-added in the adjusted nominal value added in the two subsequent periods, and where $\bar{v}_{INT,j,t}$ represents the average share of nominal new intangible investments in the nominal adjusted value added in the two subsequent periods.

The inclusion of new intangible capital types also requires us to recalculate the internal rate of return. First, note that total capital compensation at the sectoral level becomes:

[D.3] $$CAP_{adj,j,t} = VA_{adj,j,t} - LAB_{j,t}$$

where $LAB_{j,t}$ represents total labor compensation in sector j. The nominal rate of return for industry *j* is defined as follows:

[D.4] $$i_{j,t} = \frac{CAP_{adj,j,t} + \sum_k (p^I_{k,j,t} - p^I_{k,j,t-1}) A_{k,j,t} - \sum_k p^I_{k,j,t} \delta_{k,j,t} A_{k,j,t}}{\sum_k p^I_{k,j,t-1} A_{k,j,t}}$$

where $p^I_{k,j,t}$, $\delta_{k,j,t}$, and $A_{k,j,t}$ are respectively the price index, the depreciation rate, and the real capital stock of asset type *k*. Using this internal rate of return, we then calculate the user cost of capital $q_{k,j,t}$ for asset type *k* such that:

[D.5] $$q_{k,j,t} = p^I_{k,j,t-1} i_{j,t} + p^I_{k,j,t} \delta_{k,j,t} - [p^I_{k,j,t} - p^I_{k,j,t-1}]$$

The compensation to asset type *k* is obtained through the following equation:

[D.6] $$CAP_{adj,kj,t} = q_{k,j,t}A_{k,j,t}$$

Thus, we are ready to state the capital services growth as follows:

[D.7] $$\Delta lnK_{j,t} = lnK_{j,t} - lnK_{j,t-1} = \sum_k \overline{w}_{k,j,t} \Delta lnA_{k,j,t}$$

where $\overline{w}_{k,j,t}$ denotes the share of asset *k* in total capital compensation such that:

[D.8] $$\overline{w}_{k,j,t} = \frac{q_{k,j,t}A_{k,j,t}}{\sum_k q_{k,j,t}A_{k,j,t}}$$