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Hamburg Discussion Paper in International Economics [No.16]

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Is the EU ready for the next generation of investment?

The case of France and Germany¹

By Alberto Nonnis^{*}, Felix Roth^{**} and Ahmed Bounfour^{***}

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Abstract

This paper presents a puzzling finding: although France invests twice as much in intangible capital vis-à-vis Germany, both countries have similar LPG rates over the studied period from 1995 until 2020. We find that this difference in investments is driven by France's four- and two-and-a-half-fold investments in software and organizational capital. Our paper offers three perspectives to clarify the puzzle. First, higher investments in intangible capital in France might suggest a better readiness of the country towards the next generation of investment. However, France's investments in intangibles appear to be less efficient compared to those of Germany. Third, measurement problems in the software and organizational capital investment series are also to be considered to understand this major puzzle.

Keywords: Intangible capital; Labour Productivity; Germany; France; EU

1. Introduction

As discrepancies in investment levels in intangible capital between countries can significantly account for differences in productivity, understanding the dynamics of intangible capital - now the key factor - and its impact on labor productivity growth (henceforth, LPG) is critically important for the future development and economic competitiveness of the EU.

¹ We would like to thank Christian Rammer for his excellent comments.

Notably, the observed deceleration in productivity may, in part, be attributed to a delay in realizing the benefits of investments in intangible assets. As suggested in the literature Brynjolfsson *et al.*, 2021; Miyagawa *et al.*, 2021), productivity growth tends to be lower during the investment period in a new technology, and its positive benefits manifest in a subsequent period. Consequently, productivity over time assumes a J-shaped pattern, a phenomenon commonly called the “productivity J-curve.” Specifically, this is the case with general-purpose technologies such as Artificial Intelligence (AI, hereafter), which, as noted by Brynjolfsson *et al.* (2021), requires meaningful complementary investment to manifest its productivity benefits.

In this study², we undertake a comparative sectoral analysis between France and Germany - two leading EU countries - and highlight an investment puzzle that sees the two countries having similar LPG rates despite very different capital investment patterns. In fact, according to the latest EUKLEMS/INTANProd data, France has emerged as a leading nation in Europe and the EU in the accumulation of intangible capital, strongly outpacing its investment in tangible capital, similar to what observed in the US (Roth 2024a). In contrast, Germany has invested significantly less than tangible investments and as a percentage of total output over the same period. This variance can be attributed primarily to France’s substantial software and organizational capital investments. Our analysis aims to understand these differences and assess the respective readiness of the two countries for the next generation of technology wave, especially AI and complementary investments in intangibles that it requires.

One of the central questions is whether these differences result from disparities in the industry structure and business models of these two economies. Notably, it is puzzling that these variations do not significantly affect economic performance. Specifically, as highlighted by *France-Stratégie* (Guillou *et al.* 2018), France's high levels of intangible investment do not translate into satisfactory better performance compared to other EU countries, particularly Germany, which exhibits similar rates of LPG.

To examine this, we conducted an econometric analysis on a panel of 15 European and EU countries observed from 1995-2019. We utilize sectoral data from the most recent EUKLEMS/INTANProd release (Bontadini *et al.* 2023), and apply an econometric cross-country sectoral growth accounting (CCSGA) approach to derive the specific impact for France and Germany. Our econometric findings for the EU-15 suggest that non-R&D intangible

² This study is the result of a collaboration between members of the Horizon 2020 European project GlobalInto, concluded in 2022. For more information on the project, visit <https://globalinto.eu/>.

capital, such as organizational capital, training, design, and tangible capital, play a pivotal role in enhancing LPG. Whereas the impact of organizational capital and training on LPG is strongly driven by the market service sector, the impact of tangible capital on LPG is key in the goods sector. Our CCSGA finds that overall Germany's investment in intangible capital is slightly more efficient than the one in France.

In addition to these insights, our research also aims to address the measurement issue concerning intangible investments in France and Germany, subsequently delineating the key characteristics of each country's behavior regarding intangible investments. Our research suggests that Germany's investments in software and organizational capital are likely too low, and France's investments in software and organizational capital are likely slightly too high.

Finally, the paper will provide valuable policy insights, offering the potential for bench learning between the two countries and considerations for an expanded policy agenda at the national and European levels, including a call for harmonization of the measurement of software and organizational capital at the national and European levels.

The paper is structured as follows. The next section presents the relevant literature on intangible capital. Section 3 introduces the theoretical framework. Section 4 outlines the data used, while Section 5 provides the relevant descriptive evidence for France and Germany at both national and sectoral levels. Section 6 presents the econometric and growth accounting results and a discussion on measurement issues, section 7 discusses the findings and offers policy implications and section 8 concludes.

2. Intangible capital: literature and theoretical background

With the ongoing digitalization of economies and evolving technological advancements, intangible capital is assuming increased importance as a crucial productive factor. While the role of intangibles in the production function has been acknowledged since the emergence of endogenous growth models in the 80s (Lucas Jr 1988; Romer 1990), primarily focusing on elements such as R&D to explain economic growth, it is only in more recent times that the scope of intangible assets has been broadened.

Research recognized that various forms of expenditure in intangible assets are gaining increasing importance, many of which are not adequately accounted for in national accounts, an issue that has led to a misrepresentation of national accounts (Brynjolfsson et al. 2002;

Nakamura 2001). Addressing this issue, Corrado et al. (2005) made a pivotal contribution by emphasizing that numerous intangible types should be adequately capitalized in national accounts, treating their expenditure not merely as costs but as investments.

Another significant contribution from Corrado et al. (2005, 2009) lies in the identification and classification of intangibles, which are inherently challenging to quantify and identify. This classification encompasses three macro categories: computerized information, innovative property, and economic competencies. Widely adopted in the literature, this categorization is reflected in industry-level intangible assets databases such as INDICSER (O’Mahony et al. 2012) INTAN-Invest (Corrado et al., 2018), and the first (Stehrer et al. 2019), and latest releases of the EUKLEMS/INTANProd database (Bontadini et al. 2023), which we employ in this study. A detailed review of the existing datasets on intangible investments can be found in Roth (2024a). In addition, a summary of the intangible types included in the classification, distinguishing those already incorporated into national accounts from those that are not, is provided in Table 1.

Table 1. Intangible Assets in the National Accounting

	Intangible asset	NA
Computerized information		
	Computer software and databases	Yes
Innovative property		
	Research and development	Yes
	Other intellectual property products	Yes
Economic competencies		
	Design	No
	Brand	No
	Training	No
	Organizational capital	No

Note. NA= national accounts. Source: Corrado et al. (2005), Bontadini et al. (2023).

Subsequent studies have evaluated the importance of intangible capital for production, indicating a paradigm shift in favor of these assets over traditional inputs. The seminal contributions of Brynjolfsson et al. (2002), Nakamura (2001, 2010), and Corrado et al. (2009) demonstrated the importance of intangible investment in the US, followed by impactful studies such as Roth and Thum (2013) studying an EU sample. A detailed overview of the literature at the macro- and meso-level can be found in Bavdaž et al. (2023) and Roth (2024a, 2024b).

Intangibles also emerge as potential explanatory factors for the “productivity puzzle,” the observed slowdown in labor productivity and total factor productivity (TFP) growth observed globally over the past two decades, coinciding with the surge of new technologies. Measurements related to intangible capital might, at least partially, account for the observed deceleration (Bounfour & Miyagawa 2015; Gordon 2016; Crouzet & Eberly 2021; Kim et al. 2021; Nonnis et al. 2021; Roth 2022; Nonnis et al. 2023; Goldin et al. 2024; De Ridder 2024). Moreover, new technologies like AI can be considered general-purpose technologies, as highlighted by Brynjolfsson (2021). Investment in these technologies initially leads to underestimating productivity and TFP, as they require a certain period of time to translate their investment into productivity gains. As a result, overestimations occur in subsequent phases when the productivity gains fully manifest.

While the existing literature has extensively examined the case study of the US or cross-country-sectoral comparative studies across a large sample of EU countries (e.g. Roth and Thum, 2013; Roth, 2024b), it has not yet delved into focused case-study comparisons, such as a detailed comparison between the French and the German case. This gap in the literature underscores the novelty and importance of our research.

3. Theoretical Framework

Following Roth (2024b), our model considers the following specification:

$$Q_{cit} = A_{cit} K_{cit}^{\alpha} R_{cit}^{\beta} L_{cit}^{\gamma} \varepsilon_{cit} \quad (1)$$

where the subscripts c , i and t denote country, industry and time, respectively. Q is a measure of output, while K , R and L are productive factors: tangible capital stock, intangible capital stock and labor, respectively. Finally, A is total factor productivity (TFP) and ε is an error term.

Dividing both sides by labor and assuming that $\alpha+\beta+\gamma=1$, we obtain:

$$q_{cit} = A_{cit} k_{cit}^{\alpha} r_{cit}^{\beta} \varepsilon_{cit} \quad (2)$$

where lowercase letters denote per worker variables.

Log-differentiating the equation, we obtain:

$$\begin{aligned}
& (\ln q_{cit} - \ln q_{cit-t}) \\
& = (\ln A_{cit} - \ln A_{cit-1}) + \alpha(\ln k_{cit} - \ln k_{cit-1}) + \beta(\ln r_{cit} - \ln r_{cit-1}) + e_{cit}^3
\end{aligned} \tag{3}$$

Assuming, that the TFP growth term $(\ln A_{cit} - \ln A_{cit-1})$ has a time dependent common factor μ_t across counties and sectors and a vector of Nelson –Phelps (1966) control variables yields:

$$(\ln A_{cit} - \ln A_{cit-1}) = c + gH_{ct} + mH_{ct} \frac{q_t^{max} - q_{ct}}{q_{ct}} + n(1 - ur_{ct}) + \rho \sum_{i=1}^k X_{ct} + \mu_t \tag{4}$$

where c is a constant, H_{ct} represents innovation capacity, $H_{ct} \frac{q_t^{max} - q_{ct}}{q_{ct}}$ is a catch-up term, $(1 - ur_{ct})$ represents business cycles and X_{ct} a vector of control variables that may affect TFP, while μ_t are time fixed effects.

Inserting equation (4) into equation (3), we finally obtain:

$$\begin{aligned}
& (\ln q_{cit} - \ln q_{cit-t}) = c + gH_{ct} + mH_{ct} \frac{q_t^{max} - q_{ct}}{q_{ct}} + n(1 - ur_{ct}) + \rho \sum_{i=1}^k X_{ct} + \mu_t + \\
& \alpha(\ln k_{cit} - \ln k_{cit-1}) + \beta(\ln r_{cit} - \ln r_{cit-1}) + e_{cit}
\end{aligned} \tag{5}$$

The equations $(\ln k_{cit} - \ln k_{cit-1})$ and $(\ln r_{cit} - \ln r_{cit-1})$ are estimated using capital services growth (see Appendix C for a detailed overview of the calculations).

4. Data and definitions

The data used in this study is obtained from the most recent version of the harmonized EUKLEMS/INTANProd 2022 database (Bontadini et al. 2023), which provides comprehensive information on productive inputs and outputs for 15 European countries⁴, the United States and Japan for the period 1995-2020. The variables gathered for analysis encompass data on both tangible and intangible capital as well as labor productivity, computed as the ratio of value added at constant 2015 prices to the total hours worked by employees.

More precisely, both tangible and intangible capital include gross fixed capital formation, computed as 2015 chained linked volumes, and capital stock, which is used in computing the capital services variables, used in the econometric analysis.

³ Where $e_{cit} = \ln \varepsilon_{cit} - \ln \varepsilon_{cit-1}$

⁴ Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Latvia, Lithuania, Netherlands, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.

Tangible capital variables comprise the aggregation of five subcategories within the dataset: computing equipment (IT), communications equipment (CT), transport equipment (TraEq), other machinery and equipment (OMach), and total non-residential investment (OCon); residential structures (RStruc) are notably excluded from these computations.

Regarding intangible capital, the classification employed in the EUKLEMS/INTANProd database follows the framework outlined by Corrado et al. (2005), categorizing intangibles in three groups: software and databases; innovative property, which includes R&D and design; and economic competencies, which includes training, brand, and organizational capital. Notably, it should be emphasized that among these intangible capital categories, only R&D and software and databases are already capitalized in national accounts, while the remaining components are not capitalized, and thus do not contribute to value added calculations.

Sectors are classified according to the classification in the EUKLEMS/INTANProd database, which, in turn, follows the NACE Rev. 2 classification. We employ 1-digit codes and a categorization into two broad subgroups following Roth (2024b):

1) Market Economy, which includes the 1-digit sectors: A – Forestry and fishing, B - Mining and quarrying, C – manufacturing, D – Electricity, gas, steam and air conditioning supply, E – Water supply, sewerage, waste management and remediation activities, and F – Construction, G – Wholesale and retail trade, repair of motor vehicles and motorcycles, H – Transportation and storage, I – Accommodation and food service activities, J – Information and communication, K – Financial and insurance activities, M – Professional, scientific and technical activities, N – Administrative and support service activities, R – Arts, entertainment and recreation, and S – Other service activities.

2) Goods producing, which include 1-digit sectors A – Forestry and fishing, B - Mining and quarrying, C – manufacturing, D – Electricity, gas, steam and air conditioning supply, E – Water supply, sewerage, waste management and remediation activities, and F – Construction.

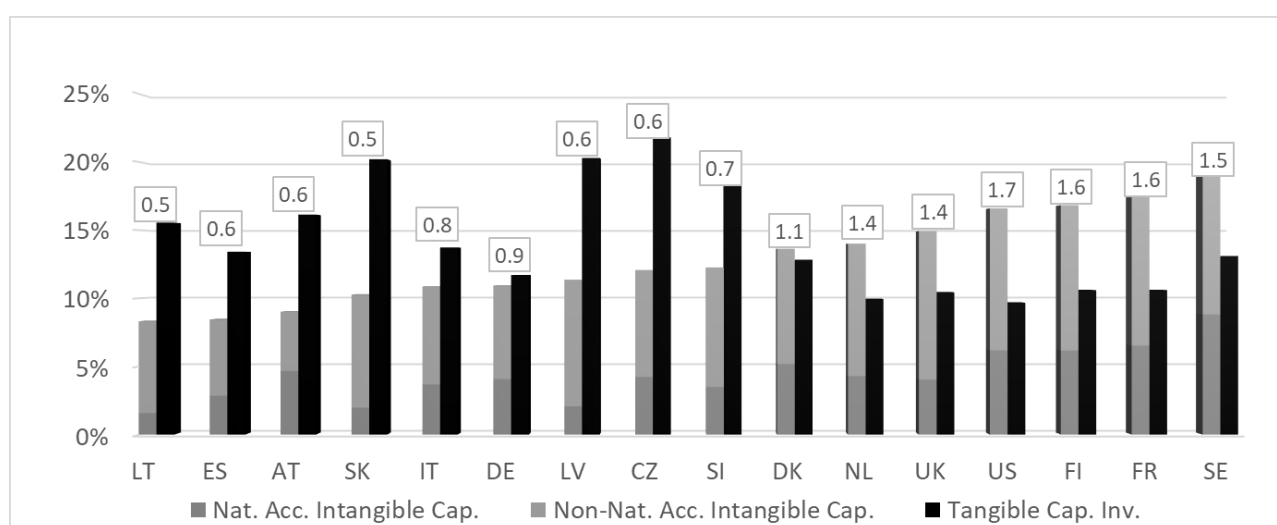
3) Market services, which include G – Wholesale and retail trade, repair of motor vehicles and motorcycles, H – Transportation and storage, I – Accommodation and food service activities, J – Information and communication, K – Financial and insurance activities, M – Professional, scientific and technical activities, N – Administrative and support service activities, R – Arts, entertainment and recreation, and S – Other service activities.

5. Intangible investment and labor productivity

5.1 Intangible capital in France and Germany

Figure 1 displays intangible capital investments, divided into those recorded in national accounts and those that are not recorded, and tangible average capital investments for the 15 European and EU countries in our sample and the US from 1995 to 2020, presented as a percentage of value added. The data illustrates that France leads in intangible capital investment across Europe and the EU, second only to Sweden. Conversely, Germany lags significantly and falls in the middle of the countries depicted. This discrepancy is strongly attributable to differences in national account intangibles (7% vs. 11%), but France has invested more even in non-national account intangibles (4% vs. 7%). Interestingly, this contrast does not apply to tangible capital, as Germany and France invest similar figures, placing them among the countries that invest less in Europe and the EU as a percentage of value added.

Figure 1. Average 1995-2020 intangible and tangible capital investments as a percentage of value added in selected countries.

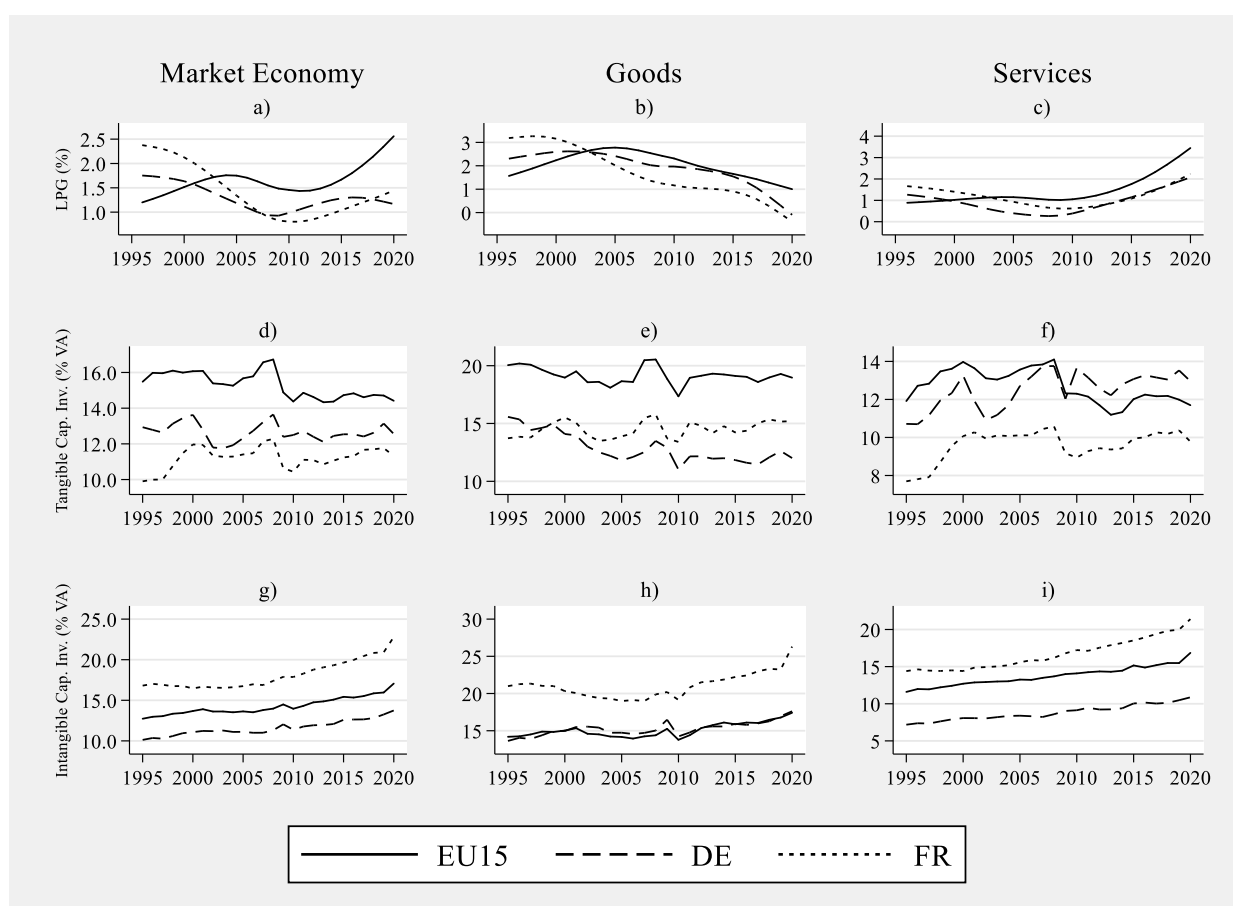


Notes. Investments in tangible and intangible assets are expressed as a percentage of gross value added adjusted for intangibles (volumes). Countries are sorted according to their overall investments in intangible capital. The ratio displayed above each country's bar chart depicts the share of intangible capital investments over tangible capital investments.

For a detailed comparison of the French and German cases, Figure 2 compares the trends in LPG, tangible capital and intangible capital from 1995 to 2020, for the Market Economy, the Goods sector and the Market Services sector. Expressed as a percentage of value added, the patterns illustrate similar trajectories of LPG in both countries in the Market Economy (panel

a), as well as in the Goods (panel *b*) and Market Services sector (panel *c*). In the Goods sector, both countries see a steady decline in LPG. In the Market services sector, both countries experienced low growth rates until 2010. From 2010 onward, we witnessed an acceleration in France's and Germany's services sector. However, LPG in the EU15 accelerated even more significantly than in France and Germany.

Figure 2. Labor productivity, tangible and intangible capital investment over time, 15 EU countries, 1995-2019.



Notes. Investments in tangible and intangible assets are expressed as a percentage of gross value added adjusted for intangibles (volumes). Labor productivity is defined as gross value added divided by the total hours worked by employees.

The following two rows (panels *d-i*) examine investment rates in tangible and intangible capital in the two countries. Concerning tangible capital (panels *d-f*), the patterns followed by the two countries in both sectors are quite similar, with Germany investing more in the Services sector and France investing more in the Goods sector. Regarding intangible capital (panels *g-i*), France invested significantly more than Germany in both sectors, with this difference growing notably in the final ten years of the sample, particularly in the Services sector. Figure 2 indicates that

even if France invested twice as much in intangible capital, its LPG has been similar to that of Germany.

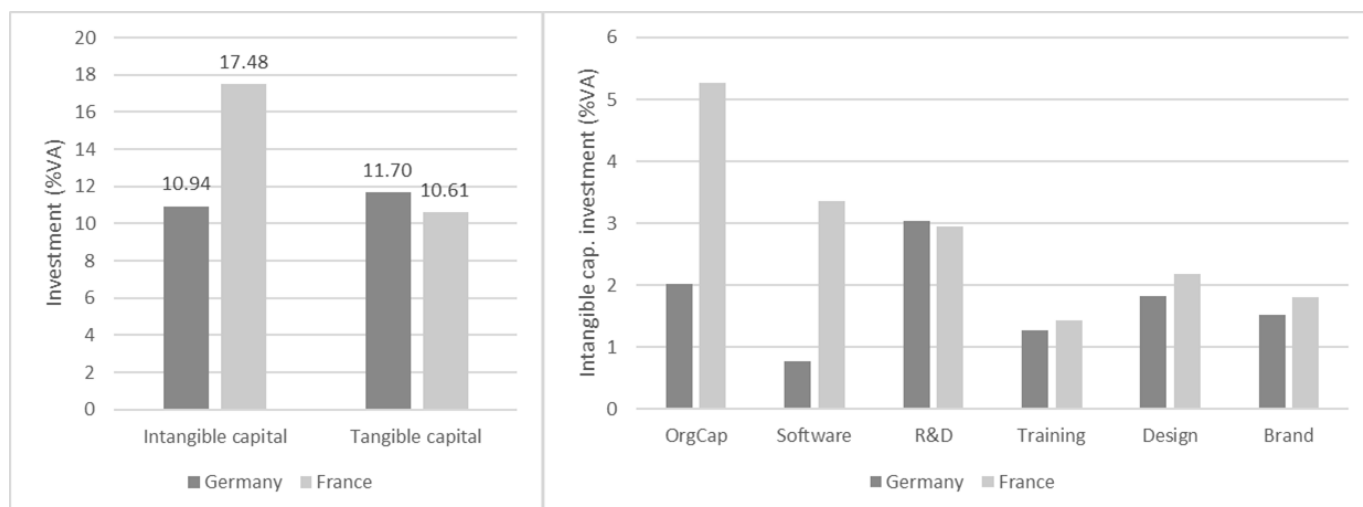
Table 2. Intangible and tangible capital investment in France and Germany 1995-2020

Country	Year	Software	R&D	Design	Brand	Training	OrgCap	Intang. capital	Tang. capital
DE	1995	7.57	41.99	24.57	21.84	21.17	27.88	152.82	187.07
		0.48%	2.68%	1.57%	1.39%	1.35%	1.78%	9.74%	11.93%
DE	2000	10.75	50.34	30.59	26.49	22.62	32.08	182.22	221.06
		0.62%	2.92%	1.77%	1.53%	1.31%	1.86%	10.55%	12.80%
DE	2005	12.08	50.62	31.32	25.53	22.35	35.47	185.81	203.17
		0.68%	2.85%	1.76%	1.44%	1.26%	2.00%	10.47%	11.45%
DE	2010	15.19	56.55	33.59	26.05	23.73	38.01	201.21	216.88
		0.81%	3.02%	1.79%	1.39%	1.27%	2.03%	10.73%	11.57%
DE	2015	20.64	65.48	41.10	35.30	25.33	47.07	245.84	238.83
		0.99%	3.15%	1.98%	1.70%	1.22%	2.26%	11.82%	11.48%
DE	2020	25.35	81.41	43.19	37.27	27.28	49.57	275.24	254.62
		1.19%	3.82%	2.03%	1.75%	1.28%	2.32%	12.91%	11.94%
FR	1995	21.70	30.97	20.29	16.54	15.78	51.77	160.25	91.47
		2.21%	3.15%	2.07%	1.68%	1.61%	5.27%	16.32%	9.31%
FR	2000	31.62	32.17	22.44	20.00	17.05	58.88	187.12	133.79
		2.68%	2.73%	1.90%	1.69%	1.44%	4.99%	15.85%	11.34%
FR	2005	37.95	34.62	25.52	22.42	17.81	63.37	208.20	139.18
		2.94%	2.68%	1.98%	1.74%	1.38%	4.91%	16.13%	10.78%
FR	2010	45.76	40.49	29.10	24.99	19.23	70.93	237.52	136.03
		3.39%	3.00%	2.16%	1.85%	1.43%	5.26%	17.62%	10.09%
FR	2015	56.08	44.69	35.84	28.09	20.41	79.36	271.92	152.69
		3.90%	3.11%	2.49%	1.95%	1.42%	5.52%	18.92%	10.62%
FR	2020	78.05	47.65	41.74	30.23	20.25	91.19	316.64	154.64
		5.45%	3.33%	2.91%	2.11%	1.41%	6.36%	22.10%	10.79%

Note: Tangible and intangible capital investments are expressed in billions of euros. Percentages below the values indicate values as a percentage of value added.

Table 2, which presents intangible and tangible capital investments in billions of euros and in the percentage of value added for the 5-intervals from 1995-2020 in France and Germany, helps contextualize the patterns found in Figures 1 and 2. In both countries, the growth of intangible capital investment remains relatively stable throughout the entire period. When examining the data at five-year intervals, even the decline in 2007 does not appear to be particularly pronounced. Conversely, tangible capital investment in both countries remained stagnant for approximately a decade, from 2000 to 2010. This stagnation can only be partially attributed to the financial crisis, which had already commenced before 2005. While France's investment in software and databases is relatively high, at 5.45% in 2020, Germany's investments remain as low as 1.19% in 2020. The same holds for investments in organizational capital, which are as high as 6.36% in France in 2020 but only take a value of 2.32% for Germany in 2020.

Figure 3. Investment in intangible and tangible assets by type, as percentage of value added, average values 1995-2020



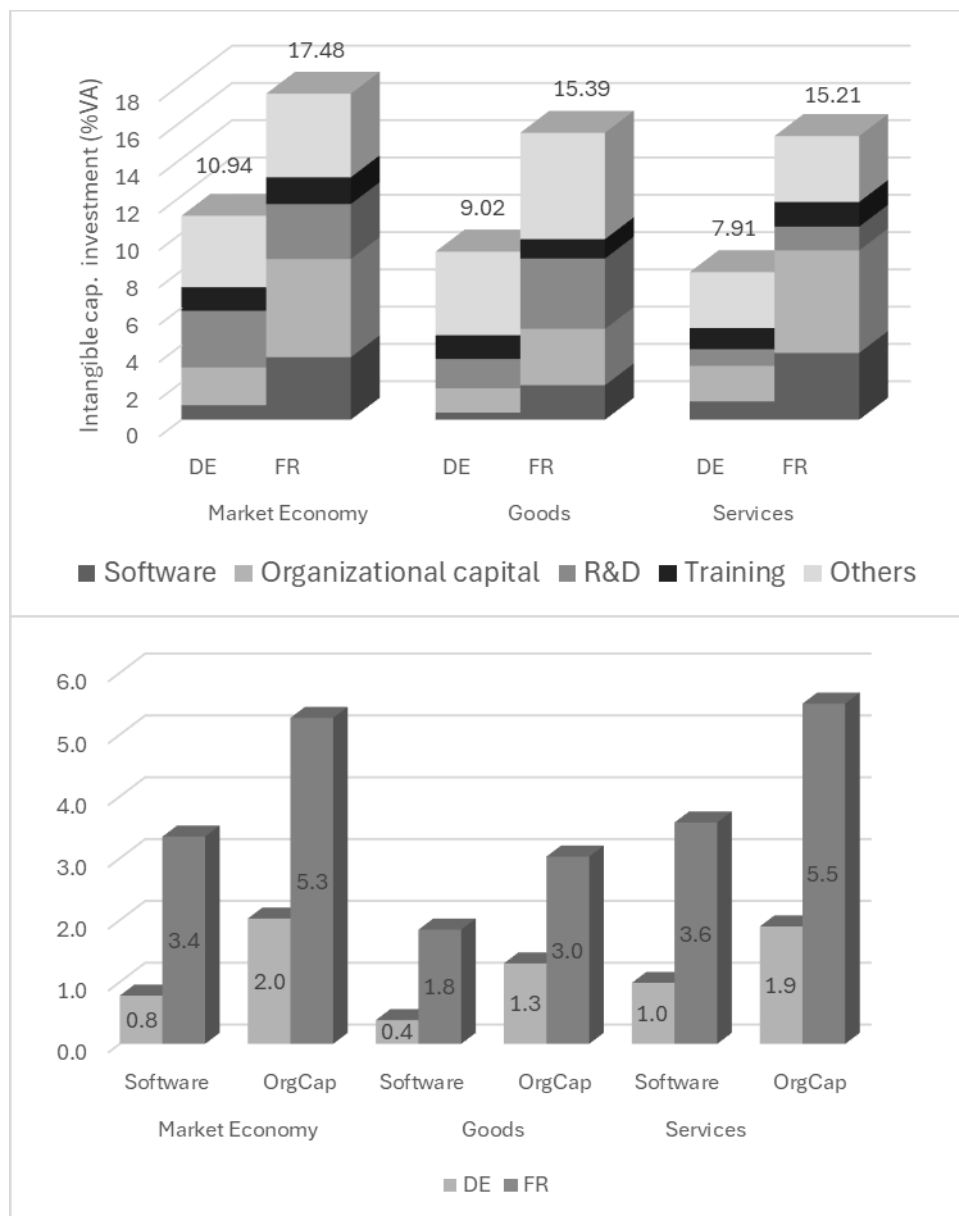
Notes. The figures compare Tangible and Intangible capital average investment over the period 1995-2020. Panel (a) and (b) provide the same information but panel (a) outlines the comparison between total intangible and tangible investments.

In order to further emphasize our findings from Table 2, Figure 3 displays the average intangible and tangible capital investments as percentage of value added for the period 1995-2020 by type of capital investment. It further confirms that the majority of the discrepancies between the two countries stem from investment in organizational capital (2.03% vs 5.27% of value added), and software (0.78% vs 3.35%). On the other hand, other intangible capital categories including R&D, training, design and brand, as well as tangible capital exhibit similar values.

5.2 Sectoral analysis

A closer examination of sectoral groups helps in understanding these differences. Figure 4 illustrates the average intangible investment as percentage of value added for France and Germany during the period 1995-2020. The data is segmented across the three broad groups previously mentioned (market economy, goods producing and market services) and for four types of intangibles (R&D, software, training and organizational capital). The figures clearly show that France invested more than Germany in intangible assets. The strong divergence is

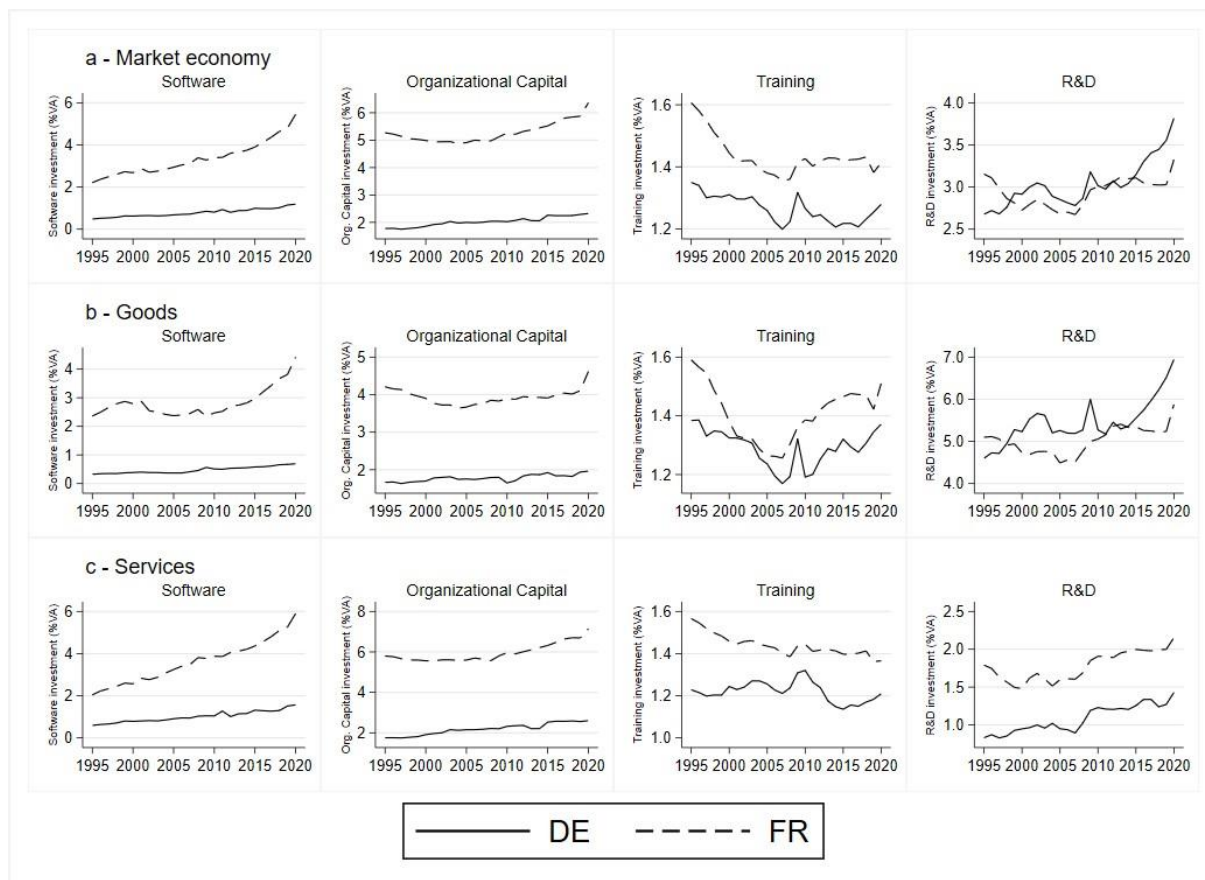
Figure 4. Intangible investment as percentage of value added. Average values 1995-2020.



Note. Investments in intangible assets are average values over the period 1995-2020, expressed as percentage of gross value added adjusted for intangibles (volumes). Numbers inside the bars refer to total intangibles over value added.

attributed to substantial disparities in software and organizational capital investments, where France significantly exceeded Germany's contributions overall and in both sectors: goods and markets services. The differences are particularly stark when it comes to market services, where France invests nearly four times the amount in software and three times the amount in organizational capital.

Figure 5. Intangible capital investment over time, Market economy (a), Goods (b) and Services (c).



Note. Investments in intangible assets are expressed as a percentage of gross value added adjusted for intangibles (volumes).

Figure 5 illustrates the evolution of intangible investment, as percentage of value added, over the period 1995-2020 for the same four categories of intangible assets for the market economy and for the Goods and Services sectors. The figure further underlines the stark disparities between France and Germany concerning investments in software and organizational capital. Whereas we detect a notable increase in software investment in France over the last 10 years, especially in the Services sector, investments in software in Germany have remained almost stagnant and at much lower levels, even during the lockdown period during the COVID-19 pandemic in 2020. A very similar pattern holds once more for investments in organizational capital.

6. Econometric analysis

6.1 GMM Results

We estimate our model using the system GMM estimator introduced by Arellano and Bover (1995), Blundell and Bond (1998), and Bond et al. (2001), in order to control for potential endogeneity of factors. The estimation results for the 1-digit industry sample are presented in Table 3. Our estimation covers the EU-15 for the period 1995-2019 for the overall market economy (regression 1), the services sector (regression 2), and the goods sector (regression 3). The year 2020 has been excluded from the estimations due to the COVID-19 shock.

In line with the existing literature, which studies an EU-10 country sample for the period 1995-2018 (Roth 2024a), Table 3 shows that non-R&D intangibles and tangible capital are the main drivers of LPG in the market economy. Specifically, within the market economy (regression 1), organizational capital, vocational training, design, and tangible capital emerge as the most influential capital types, with coefficients ranging between 0.12 for training to 0.16 for organizational capital. While the market services sector largely drives these effects for the market economy for the non-R&D intangibles, the goods sector is strongly responsible for the effect of tangible capital on LPG. The non-significance of R&D indicates that R&D is losing importance at the aggregated sectoral level in modern economies (Roth et al., 2023; De Ridder, 2024). However, as also noted by De Ridder (2024), this observation may be influenced by differences in the impact of R&D between high-tech and low-tech firms, with R&D concentrated in a limited number of highly digitized firms, while smaller players primarily rely on spillover effects.

Put another way, intangibles are found to be particularly impactful for Services, where almost all of them are positive and significant, except for R&D and brand. On the other hand, in the goods sector only organizational capital among intangible assets is found to be significantly positive, highlighting that production in the sector is still prevalently anchored to traditional inputs such as tangible capital.

Overall, given the scarce significance of R&D, the results from Table 3 underscore the growing significance of non-R&D intangibles complementary to AI, such as organizational capital and training, over traditional inputs like R&D, and the relative importance of the Services sector over the Goods sector. This is also evidenced by the strong impact of software and databases found in the services sector, although not significant in the goods sector and in the market economy.

Table 3. Production function estimations. 1-digit industries. Market economy, Goods and Services sectors, EU-15, 1995-2019

	(1)	(2)	(3)
	Market Economy	Services	Goods
Tangible Capital	0.13*** (3.18)	0.085** (2.16)	0.23** (2.03)
Computer Software & Databases	0.025 (1.50)	0.047*** (2.74)	0.029 (0.79)
Research & Development	0.0081 (0.65)	0.0048 (0.35)	-0.011 (-0.32)
Design	0.13*** (2.66)	0.11** (2.18)	0.050 (0.44)
Brand	0.0045 (0.13)	0.046 (0.95)	-0.047 (-0.73)
Organizational Capital	0.16*** (4.07)	0.17*** (3.84)	0.16* (1.99)
Training	0.12*** (4.12)	0.13*** (3.07)	0.097 (1.14)
<i>First-Lag Instruments</i>	1 15	1 9	1 4
<i>No. Of instruments</i>	184	124	74
<i>AB Test AR(2)</i>	0.49	0.18	0.71
<i>Hansen Test</i>	0.25	0.20	0.22
<i>N Sectors</i>	193	123	70
<i>Time Series</i>	23	23	23
<i>Observations N x T</i>	3691	2402	1289

Notes. ***, **, and * indicate significance at 1, 5, and 10 %, respectively. t-statistics are reported in parentheses. The dependent variable is labor productivity growth. All regressions are estimated using the GMM method. Each estimation includes year dummies and Nelson and Phelps (1966) control variables. Column (1) refers to the overall market economy, column (2) to the Services sector, and column (3) to the Goods sector. In the AR tests, the null hypothesis is the absence of serial correlation in the error term. In the Hansen test, the null hypothesis is the exogeneity of instruments. Instruments are chosen to maximize the efficiency of the Hansen test. The year 2020 has been excluded from the estimations due to the COVID-19 shock. Outliers exceeding ± 5 standard deviations from the mean have been removed.⁵

6.2 Growth accounting analysis

In this section, we conduct a cross-country growth accounting exercise as in Roth (2022, 2024b) to evaluate the relative contribution of the asset types to LPG in France and Germany⁶. This method allows us to decompose the sources of LPG for both countries, based on the 1-digit elasticities estimated in Table 3. The results are presented in Figure 6, where panel (a) refers to the market economy sample, panel (b) to the Goods sample, and panel (c) to the Services

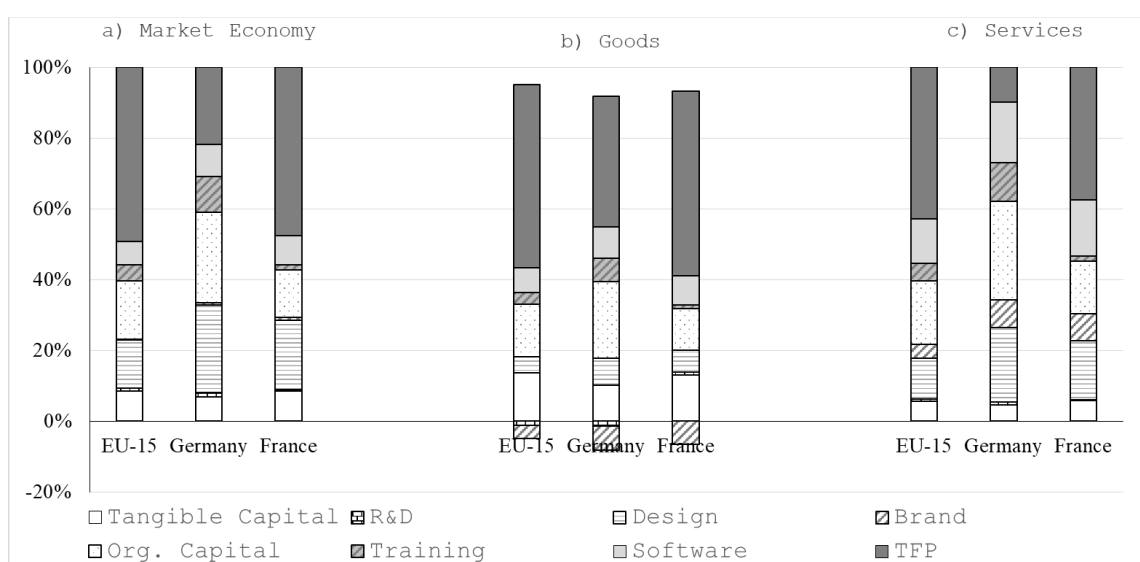
⁵ Several outlier rules have been considered. We opted for a relatively conservative approach, as other rules would have resulted to an exclusion of too many observations without significantly altering our main results.

⁶ The procedure for calculating the growth accounting coefficients calculations is detailed in Appendix D.

sample, with comparisons made among 15 European and EU countries (EU-15), Germany and France, in each panel. The summarized results from Figure 6 are as follows.

For the EU15, in the market economy, intangible capital explains approximately 43% of the total LPG variability, while tangible capital accounts for only 8%. This indicates lower marginal productivity of tangible capital, signaling its diminishing importance in modern economies. This trend is particularly pronounced in the Services sector, where intangibles explain approximately 51% of LPG, compared to 24% in the Goods sector. Organizational capital, design, software, and training emerge as the most important types of intangible capital, explaining over 16%, 14%, 7% and 5% of LPG, respectively. Brand (0.5%) and R&D (1 %) explain relatively smaller shares.

Figure 6. Growth accounting estimates. Market Economy, Goods and Services.



Note. Computations are based on the 1-digit GMM coefficients presented in Table 3. A comprehensive explanation of the methodology employed can be found in Appendix D.

A greater impact of intangible capital is found in Germany rather than France. In Germany, intangibles constitute a significant portion of LPG in the market economy (72%), mainly originating from the Services sector (approximately 85%). Conversely, in France, while the share of intangibles is substantial, it is lower (44% in the market economy, 56% in Services) compared to Germany. This suggests greater efficiency in Germany's intangible compared to France, despite Germany investing less than France and the EU15 average. In this regard, France's level of productivity for intangibles is similar to those high investing countries in EU

(e.g., Sweden⁷). Analyzing individual intangible types and focusing on organizational capital and software and training, we find that:

- Organizational capital is a major driver of the disparities between France and Germany. It accounts for 16% of LPG in the market economy (15% in Goods and 18% in Services). Its impact is significantly larger in Germany (25%, 23%, and 29%), whereas in France, it is more in line with the average of the rest of the sample (14%, 12%, and 15%).
- An important role is found for software and databases. Its effect on the market economy, amounting to 7% in the EU-15, 9% in Germany vs 8% in France, primarily stems from Services, representing 16-17% in both countries, and 12% in the whole sample.

6.3 Measurement issues

Section 6.2 showed that a part of the investment puzzle between Germany and France is related to efficiency. However, given the stark discrepancy in investment levels between the two countries, efficiency alone provides only a partial explanation for the existing puzzle. We believe that a more plausible explanation lies in measurement issues concerning investment in software and organizational capital.

First, we summarize the measurement of software investments in France and Germany. Table 4 shows the average software investment rates as a percentage of value added for selected industries in both countries, including total manufacturing (C), manufacture of machinery and equipment (C28), manufacture of vehicles (C29-C30), information and communication (J), financial and insurance activities (K) and professional, scientific and technical activities (M).⁸ As mentioned above, the ratio (FR/DE) for the market economy is 4.3 (3.35/0.78), indicating that France invested on average 3.35% of its value added in software compared to Germany's 0.78% over the period from 1995 to 2020. While this difference is already puzzling for two equally advanced and deeply integrated economies, it becomes even more compelling when analyzing single sectors and sub-sectors. For instance, within manufacturing, France invested almost 9 times more in software. Looking closer at specific sub-sectors known for Germany's strong industrial performance, such as the manufacture of motor vehicles or manufacture of machinery and equipment, we find that France invested 4.4 and 12.4 times more in software per unit of value added, respectively. A similar picture emerges in business services sectors J,

⁷ The growth accounting results for the entire sample of 15 countries are presented in Appendix E.

⁸ We refer to table F1 in Appendix F for a comprehensive overview of all sectors, and to Figure F1 for the time series patterns in the selected industries.

K and M, where France invested up to 5 and 7 times more than Germany. These huge differences are evident across nearly all sectors of the French and German economy (see Table F1 in Appendix F).

Such pronounced differences in software investment between France and Germany, despite their close economic integration within the EU and Eurozone, cannot be attributed solely to their actual industrial or firm performance. Instead, they are more likely the result of disharmonized measurement of software and embedded (in-house) software investments in the two countries.⁹

Table 4. Levels and Ratios of Investments in Software and Organizational Capital in selected Sectors, France and Germany, average values 1995-2020

Industry Name	Industry Code	Computer Software			Organizational Capital		
		DE	FR	FR/DE	DE	FR	FR/DE
Manufacturing	C	0.53	4.68	8.8	2.05	4.63	2.3
Manufacture of machinery and equipment	C28	0.34	4.23	12.4	2.22	5.22	2.4
Manufacture of motor vehicles	C29-C30	1.1	4.79	4.4	1.99	3.33	1.7
Information and communication	J	4.36	12.71	2.9	2.88	6.61	2.3
Financial and insurance activities	K	0.92	4.97	5.4	3.31	10.13	3.1
Professional, scientific and technical activities	M	0.73	5.12	7.0	4.11	7.99	1.9
Market economy	MARKT	0.78	3.35	4.3	2.03	5.27	3.4

Notes: Sectors are selected for their relative importance and comparability in the two countries. Numbers refer to average values as percentage of value added over the period 1995-2020.

Second, we summarize the measurement of organizational capital. The current version of the EUKLEMS/INTANProd data release (Bontadini et al. 2023) measures investments in organizational capital – following Corrado et al. (2005 p. 29) – by attributing 20% of manager salaries as investments in organizational capital.¹⁰ The EUKLEMS/INTANProd data release (Bontadini et al. 2023) uses the Structural of Earning Survey, which provides information on the annual earnings and number of employees by occupation¹¹. The crucial question here pertains to the quantity of managers in France and Germany. Might it be that France has a significantly higher portion of managers than Germany? Might this discrepancy be attributed

⁹ At large German corporations such as Bosch, Siemens and car manufacturers, software should account for a sizeable portion of total R&D expenditure, amounting to at least 1/4. For example, Bosch 2022 annual report indicates that 44,000 of its 85,500 R&D employees are software developers. At Siemens, software revenue in industrial process technology accounts for almost a quarter of total sales, suggesting that the software share within R&D is likely higher than this ratio.

¹⁰ We assume that the 20% figure was applied as the methodological background document (Bontadini et al. 2023) did not specify detailed calculation for the own-account estimate for organizational capital, although it clearly mentioned its embeddedness in the CHS 2005 framework (Corrado et al. 2005 p. 29; Roth & Thum 2013 p. 491).

¹¹ The information is provided at the three-digit level of the 2008 International Standard Classification of Occupations (ISCO).

to a lack of harmonization in the ISCO classification systems in France and Germany? Might this explain the larger investment rates, as depicted in Table 4, in organizational capital for France compared to Germany?

Our research seems to suggest this interpretation. Whereas in Germany, official statistics indicate a management share of 5% among the active population in 2017 (Schuster & Strahl 2019), in France, we observe a four-fold higher proportion of 21.7% in 2022, from 8% in 1982 (Brillet 2024). Such stark differences in the share of managers in France and Germany likely do not reflect differences in business and organizational models, but rather point to related to a lack of harmonization in the ISCO classifications between the two countries. This likely explains a large portion of the significant variance in investments in organizational capital between France and Germany.

Regarding the specific measurement of investments in own-account organizational capital, and considering our research results in line with the recommendations of Stehrer et al. (2019), who constructed the first harmonized intangible EUKLEMS dataset¹², own-account organizational capital investment data should be handled with great care, considering potential measurement issues in the ISCO classifications. Future research endeavors would need to refine both the conceptual and empirical part of the survey for organizational capital.

7. Discussion and Policy Implications

Our analysis sheds light on the investment puzzle, consisting on the different investment strategies followed by Germany and France in intangible capital over recent decades, which have had diverse impacts on LPG. This investigation gains particular relevance in the context of the increasing emphasis on investment in emerging technologies like AI and their anticipated implications for the future.

Within this framework, the case of Germany and France assumes particular relevance, with the two countries occupying opposite ends of the spectrum in Europe regarding intangible investment: France leads in Europe, while Germany lags behind, yet obtaining similar LPG rates. Three explanations emerge for this puzzle.

First, our results hold particular relevance when considered from the perspective of future growth, aligning with recent literature attributing low LPG rates to the emergence of new

¹² We refer to Roth (2024b) for an overview.

general-purpose technologies such as AI, whose effects may be seen over the long term with a delay. First, aligning with the “productivity J-curve” thesis (Brynjolfsson et al. 2021), this might indicate France’s preparation for the AI revolution and the potential of higher LPG in the future.

Second, in line with the suggestions by *France-Stratégie* (Guillou et al. 2018), our results indicate that parts of the investment puzzle are due to differences in efficiency. As Germany invests less in absolute terms, its investments yield a pronounced impact on LPG, indicating greater efficiency. Conversely, France, despite its heavy investments in intangibles, struggle to reap adequate benefits. Our analysis raises the issue for France regarding the efficiency of its investments and the way they are allocated. It suggests reallocating resources towards more productive intangible types and sectors while scaling back investments in less fruitful areas.

Thirdly, the large discrepancy in intangible investments between France and Germany might be partly due to an underreporting of intangibles in Germany (Roth et al. 2023) and a potential slight over reporting in France (Guillou et al. 2018). Germany’s investment in software appears to be unusually low, with France investing four times more on average over the period considered (3.4% in France vs 0.8% in Germany) and significantly less than all other EU countries in our sample. Moreover, the low investment levels in Germany, as highlighted by official sources and well-established databases based on them, such as the EUKLEMS/INTANProd database, which we utilize in this study, are at odds with the actual industrial and firm performance in Germany. Our results indicate that Germany’s investment in software should be much higher than currently depicted in the German national accounts.¹³

Moreover, possible errors may also affect the measurement of organizational capital. The large differences between the two countries reflect differences in the number of managers between France and Germany. However, we advance that Germany’s management share is likely too low, whereas France’s share seems to be disproportionately high. In line with prior work by Stehrer et al. (2019), we opt for a cautious usage of the own-account data of organizational capital, due to potential biases in the ISCO classification., and recommend further harmonization of ISCO classifications between Germany and France, as well as across the EU.

Given that we identify measurement discrepancies in software and organizational capital investments between France and Germany, the first policy implication is further harmonization

¹³ We would like to highlight at this instance that addressing these measurement issues related to investments in software would increase software and, consequently, intangible capital investments in Germany. Given that software investments are incorporated in the official German GDP calculation, this would lead to an increase of Germany’s official GDP.

of data measurement at both national bi-lateral and EU level. This might need a collaborative effort involving national statistical agencies, national ministries of economics, Eurostat and other relevant stakeholders. This also holds for the harmonization of investments in organizational capital, especially regarding ISCO classifications.

Furthermore, due to the importance of intangibles for firms' performance and economic growth, urgent attention is required to address how firms account for their investments, particularly under current accounting rules such as IAS 38. The present IFRS rules for capitalizing intangibles emphasize separability, control and certainty of future benefits, and diverge from the intrinsic nature of intangible investments, such as complementarity, commonality and spillover effects, and uncertainty. There is a need to revisit these rules to align firm's accounting practices, in order to allow European firms to disclose in a straightforward and easy to implement way their level of investment in intangible assets.

8. Conclusion

In our paper, we present a puzzling finding: although France invests twice as much in intangible capital, up to four times as much in software and up to two and half times in organizational capital vis-à-vis Germany, both countries have similar LPG rates over the studied time period from 1995 until 2020. Our study suggests three possible explanations to this puzzling insight.

First, in line with the “productivity J-curve” thesis (Brynjolfsson et al. 2021), we believe that due to the fact France's much higher investments in intangible capital it might be better prepared for the ongoing and upcoming AI revolution than Germany and will see larger LPG in France in comparison to Germany in the near future. The fact that the higher investments in intangible capital in France will only yield benefits in the near future but not in the actual presence solves the identifies investment puzzle between France and Germany.

Second, reflecting the suggestions outlined by *France-Stratégie* (Guillou et al. 2018), our findings indicate that France's investments in intangibles appear less efficient than those of Germany. Intangible capital investments explain approximately 1/3 more of LPG in Germany than France. This holds for the Market Economy and is driven by the Services sectors. Hence, this implies that Germany would gain from expanding its comparatively low intangible investment rate, whereas France should consider policies aimed at enhancing the efficiency of its intangible investments.

Third, in line with the existing literature (Roth et al. 2023), we find that the stark difference in intangible investments in software and organizational capital in France and Germany is partially attributable to measurement problems. Our analysis suggests that software investments in Germany are likely underreported in national account, while, in France, these investments might be slightly overreported (Guillou et al. 2018). Similarly, investments in organizational capital are likely underreported in Germany and possibly overreported in France.

Several policy conclusions have been presented. First, our results ask for a more detailed exploration of the national accounts calculation of software in France and Germany and call for greater harmonization at the European level. Second, our findings ask for a reevaluation of the measurement of investment in organizational capital, encompassing both conceptualization and survey dimensions. Thirdly, we call for a prompt and straightforward reform of firm accounting practices to disclose the information regarding the key components of intangibles, making this information accessible to the different stakeholders. Future research endeavors should prioritize addressing these existing measurement issues in order to ensure accuracy in the harmonization of investment data for France and Germany.

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Online Appendices

Appendix A. Summary Statistics

Table A1. Summary Statistics of the variables.

	AT					FI					NL				
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max
Labour productivity	315	0.95	4.32	-11.91	23.20	220	1.14	5.55	-20.22	25.04	248	1.12	3.16	-7.45	12.89
Research & Development	315	3.46	8.95	-26.88	69.41	220	1.27	9.65	-23.01	27.05	248	1.03	10.18	-38.18	70.03
Design	315	4.35	5.48	-9.41	28.92	220	2.69	5.91	-15.35	39.07	248	3.20	6.04	-13.61	35.12
Brand	315	2.96	5.56	-19.64	26.30	220	1.26	6.94	-20.83	38.00	248	1.61	4.48	-11.74	19.24
Organizational Capital	315	0.47	6.79	-20.66	25.72	220	1.74	5.58	-17.45	32.30	248	1.50	4.39	-19.09	22.59
Computer Software & Databases	315	7.22	8.36	-14.08	78.03	220	5.40	12.58	-57.75	49.77	248	5.86	9.86	-21.79	62.68
Training	315	0.83	3.63	-10.55	17.39	220	0.24	3.71	-12.28	12.39	248	0.70	5.47	-34.79	23.37
Tangible Capital	315	0.80	3.51	-9.42	28.13	220	0.21	3.31	-8.30	11.29	248	0.33	6.79	-37.87	46.01
Secondary Education	315	80.53	3.69	73.10	85.60	220	81.59	6.21	69.60	90.10	248	71.75	4.66	64.40	79.60
Catchup Secondary Education	315	24.43	2.47	21.29	28.81	220	25.77	4.71	17.87	34.37	248	0.97	2.49	0.00	9.90
Business Cycle	315	0.95	0.01	0.94	0.96	220	0.91	0.01	0.87	0.94	248	0.95	0.01	0.93	0.98
CZ					FR					SE					
Labour productivity	303	0.89	7.38	-33.07	22.21	253	0.67	4.11	-15.28	17.03	320	1.31	5.25	-23.72	17.37
Research & Development	303	5.64	16.91	-46.74	88.22	253	0.89	11.26	-23.76	90.74	320	1.68	8.76	-19.47	83.27
Design	303	1.60	6.43	-15.81	23.79	253	2.48	3.67	-6.76	27.61	320	1.29	5.58	-21.47	15.82
Brand	303	-0.46	7.59	-33.85	22.77	253	2.32	4.23	-10.60	27.32	320	1.17	5.35	-23.95	37.04
Organizational Capital	303	2.02	4.95	-11.77	17.54	253	1.57	3.39	-6.94	27.34	320	2.13	4.77	-17.44	28.15
Computer Software & Databases	303	5.66	15.53	-43.12	77.97	253	3.94	4.95	-23.14	23.88	320	4.14	10.06	-47.51	66.00
Training	303	0.68	6.93	-22.08	20.66	253	1.45	4.70	-9.94	24.26	320	-0.49	5.38	-22.94	14.00
Tangible Capital	303	2.38	5.72	-21.10	20.77	253	1.02	3.89	-8.14	27.89	320	2.48	4.73	-18.23	20.43
Secondary Education	303	90.59	2.82	85.20	93.90	253	69.73	6.46	59.90	80.50	320	81.39	3.13	74.70	86.10
Catchup Secondary Education	303	96.02	16.63	78.01	133.75	253	7.38	1.52	3.68	10.46	320	6.28	3.99	0.56	13.13
Business Cycle	303	0.94	0.02	0.91	0.98	253	0.91	0.01	0.89	0.93	320	0.93	0.01	0.90	0.95
DE					IT					SI					
Labour productivity	259	1.25	4.82	-20.90	18.76	321	-0.05	4.44	-13.48	29.19	201	0.77	6.14	-35.57	11.32
Research & Development	259	3.66	11.42	-16.70	89.34	321	3.81	8.81	-16.24	67.26	201	4.52	20.66	-45.41	101.10
Design	259	2.62	2.85	-4.95	14.84	321	0.45	5.04	-17.43	24.59	201	2.15	5.86	-37.92	24.22
Brand	259	1.96	4.00	-21.84	14.86	321	0.25	6.26	-24.35	16.03	201	0.61	6.94	-38.36	20.86
Organizational Capital	259	1.93	3.33	-5.41	15.74	321	1.31	5.57	-24.89	26.28	201	1.00	6.37	-35.87	17.41
Computer Software & Databases	259	3.82	5.30	-12.12	27.05	321	2.67	8.46	-14.78	71.00	201	1.80	13.89	-45.46	51.71
Training	259	0.37	4.01	-15.84	13.48	321	-0.19	4.03	-16.83	9.40	201	1.30	8.86	-36.49	25.80
Tangible Capital	259	0.56	3.08	-13.61	9.44	321	0.78	3.29	-7.65	13.78	201	-0.02	7.03	-33.74	47.74
Secondary Education	259	84.49	2.32	79.90	86.90	321	52.30	7.02	39.60	62.20	201	83.73	3.69	75.80	88.80
Catchup Secondary Education	259	15.04	2.96	10.48	22.16	321	22.36	7.94	7.17	33.67	201	67.71	4.93	59.89	79.90
Business Cycle	259	0.93	0.02	0.89	0.97	321	0.90	0.02	0.87	0.94	201	0.93	0.02	0.90	0.96
DK					LT					SK					
Labour productivity	239	0.89	5.35	-21.19	22.45	112	1.36	9.70	-30.03	27.89	126	0.02	0.67	13.26	4.64
Research & Development	239	2.59	11.08	-26.61	45.14	112	11.32	25.18	-81.59	94.60	126	-0.31	4.75	36.18	47.29
Design	239	2.93	4.40	-7.19	20.61	112	2.83	10.49	-29.29	39.90	126	0.06	0.53	5.83	7.69
Brand	239	3.98	5.12	-7.82	30.47	112	1.94	12.10	-31.39	27.56	126	0.01	0.98	14.85	9.22
Organizational Capital	239	2.69	4.67	-16.37	19.15	112	6.03	9.16	-28.52	34.21	126	0.05	0.48	4.87	5.33
Computer Software & Databases	239	6.77	10.09	-28.75	46.48	112	4.79	14.21	-37.40	33.85	126	0.02	2.27	13.37	24.70
Training	239	0.06	4.34	-13.79	13.50	112	1.15	10.82	-27.90	27.73	126	0.02	0.93	13.81	7.60
Tangible Capital	239	1.29	5.40	-12.93	24.86	112	1.60	8.97	-31.91	27.42	126	0.00	0.44	6.17	10.05
Secondary Education	239	78.94	2.40	73.50	81.60	112	92.37	2.78	84.90	95.00	126	90.51	1.63	86.00	91.90
Catchup Secondary Education	239	4.42	3.52	0.00	10.87	112	113.41	12.63	100.13	149.92	126	83.40	14.87	60.44	112.87
Business Cycle	239	0.94	0.01	0.92	0.97	112	0.90	0.04	0.82	0.96	126	0.88	0.03	0.81	0.94
ES					LV					UK					
Labour productivity	319	0.72	5.12	-23.68	35.20	151	2.85	10.26	-38.03	29.60	304	0.01	0.39	8.24	3.85
Research & Development	319	3.42	6.73	-21.60	30.05	151	0.41	18.07	-35.88	69.95	304	0.05	2.11	11.39	63.71
Design	319	2.42	5.75	-19.54	26.92	151	0.50	8.94	-28.61	24.22	304	0.05	0.24	4.93	4.33
Brand	319	1.05	7.44	-26.77	31.52	151	-0.27	13.71	-36.08	30.96	304	0.01	0.36	5.34	7.47
Organizational Capital	319	1.48	5.00	-22.39	16.01	151	1.15	8.43	-25.12	22.63	304	0.03	0.24	6.92	3.27
Computer Software & Databases	319	3.78	13.18	-45.72	63.51	151	4.15	22.48	-39.55	71.68	304	0.10	1.20	15.37	41.03
Training	319	3.38	8.19	-24.06	34.01	151	1.74	9.67	-27.92	35.27	304	0.03	0.45	5.74	5.53
Tangible Capital	319	1.28	5.50	-15.38	26.24	151	1.94	9.69	-45.22	28.54	304	0.00	0.40	7.13	17.65
Secondary Education	319	49.38	8.34	33.70	61.30	151	87.54	3.23	79.20	91.20	304	72.70	7.19	54.70	81.10
Catchup Secondary Education	319	22.08	7.09	5.97	30.82	151	161.01	13.86	134.24	194.06	304	24.57	7.75	14.11	41.43
Business Cycle	319	0.84	0.05	0.74	0.92	151	0.89	0.04	0.81	0.94	304	0.94	0.01	0.92	0.96

Source: EUKLEMS/INTANProd 2022 database (Bontadini et al. 2023) and Eurostat Data.

Appendix B. List of sectors and sectoral classification

Table B1. List of 1-digit sectors and sectoral classification.

NACE code	Sector's name	2-group classification
A	Agriculture, forestry and fishing	Goods
B	Mining and quarrying	Goods
C	Manufacturing	Goods
D	Electricity, gas, steam and air conditioning supply	Goods
E	Water supply; sewerage, waste management and remediation activities	Goods
F	Construction	Goods
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	Services
H	Transportation and storage	Services
I	Accommodation and food service activities	Services
J	Information and communication	Services
K	Financial and insurance activities	Services
M	Professional, scientific and technical activities	Services
N	Administrative and support service activities	Services
R	Arts, entertainment and recreation	Services
S	Other service activities	Services

Notes : EUKLEMS/INTANProd 2022 database (Bontadini et al. 2023)

Appendix C. Capital services calculations

To calculate capital services, we begin by defining value added $\overline{VA}_{i,t}$ and the deflator index $\overline{VAP}_{i,t}$ adjusted for intangible assets that are not included in national accounts:

$$\overline{VA}_{i,t} = VA_{i,t} + \sum_k I_{k,i,t} \quad (B1)$$

$$\Delta \ln \overline{VAP}_{i,t} = \bar{v}_{VA,i,t} \Delta \ln VAP_{i,t} + \bar{v}_{Int,i,t} \Delta \ln IPINT_{i,t} \quad (B2)$$

Here, $I_{k,i,t}$ represents investment in capital asset k not included in national accounts.

Total capital compensation is then determined as:

$$\overline{CAP}_{i,t} = \overline{VA}_{i,t} - LAB_{i,t} \quad (B3)$$

Where $LAB_{i,t}$ denotes total labor compensation.

Next, the nominal rate of return of capital is formulated as follows:

$$r_{i,t} = \frac{\overline{CAP}_{i,t} + \sum_k (p_{k,i,t}^I - p_{k,i,t-1}^I) A_{k,i,t} - \sum_k p_{k,i,t}^I \delta_{k,i,t} A_{k,i,t}}{\sum_k p_{k,i,t-1}^I A_{k,i,t}} \quad (B4)$$

Here, $p_{k,i,t}^I$, $\delta_{k,i,t}$, and $A_{k,i,t}$ represent the price index, depreciation rate, and real capital stock of capital type k , respectively.

The user cost of capital is defined as:

$$q_{k,i,t} = p_{k,i,t-1}^I r_{i,t} + p_{k,i,t}^I \delta_{k,i,t} - (p_{k,i,t}^I - p_{k,i,t-1}^I) \quad (B5)$$

Compensation for each capital type is then:

$$\overline{CAP}_{k,i,t} = q_{k,i,t} A_{k,i,t} \quad (B6)$$

Finally, the growth in capital services is calculated as:

$$\Delta \ln K_{i,t} = \ln K_{i,t} - \ln K_{i,t-1} = \sum_k \bar{w}_{k,i,t} \Delta \ln A_{k,i,t} \quad (B7)$$

Here, $\bar{w}_{k,i,t}$ denotes the share of capital asset type k over total capital compensation:

$$\bar{w}_{k,i,t} = \frac{q_{k,i,t}A_{k,i,t}}{\sum_k q_{k,i,t}A_{k,i,t}} \quad (\text{B8})$$

Appendix D. Growth accounting calculations

The growth accounting coefficient for each country c and capital asset k (where $k = 1, \dots, 8$, including 6 intangible capital types, tangible capital and a residual TFP term) is obtained as:

$$GA_{c,k} = \frac{\overline{GA}_{k,c,t}}{\sum_1^8 \overline{GA}_{k,c,t}} \quad (E1)$$

That is the proportion of each asset's average (time-varying) growth accounting coefficient $\overline{GA}_{k,c,t}$ relative to the total for all assets.

Each (time-varying) growth accounting coefficient $GA_{k,c,t}$, for each of the 7 capital types, is obtained as:

$$\overline{GA}_{k,c,t} = \beta_k \gamma_{k,c,t} \quad (E2)$$

Where β_k denotes the coefficient of the GMM estimation obtained from Table 3 for each capital type k , while $\gamma_{k,c,t}$ is the (per worker) growth rate of each capital type in each period t for each country c .

Specifically, the country-level growth rate $\gamma_{k,c,t}$ for each capital type is obtained starting from the non-per capita growth Γ , using the formula:

$$\gamma_{k,c,t} = \Gamma'_{k,c,t} - \Gamma_{L,c,t} \quad (E3)$$

Where $\Gamma_{L,c,t}$ is growth in the number of workers in country c at time t , while $\Gamma'_{k,c,t}$ is the yearly average of sectoral growth rates $\Gamma_{k,c,j,t}$ of each capital type obtained weighted as in the formula:

$$\Gamma'_{k,c,j,t} = \frac{\omega_{k,c,j,t} + \omega_{k,c,j,t-1}}{2} \Gamma_{k,c,j,t} \quad (E4)$$

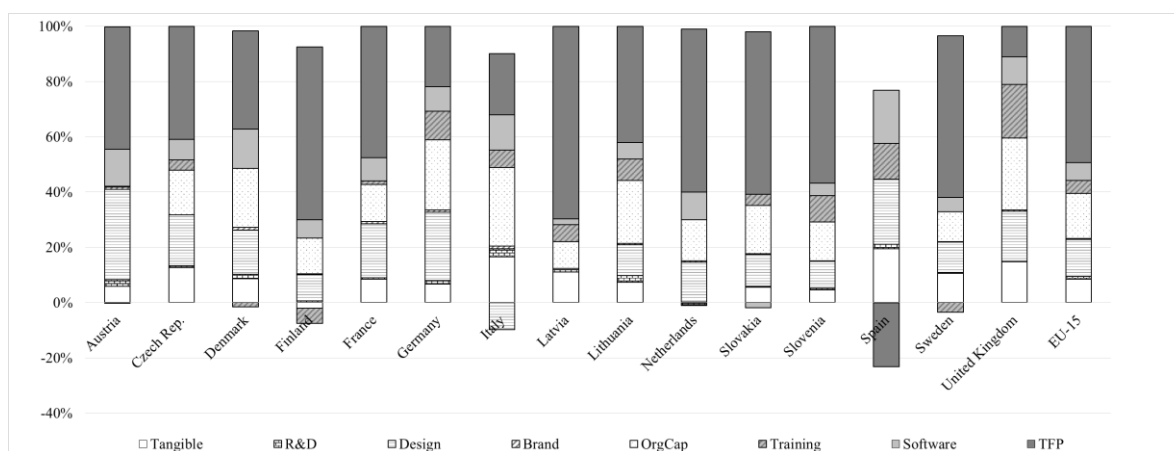
Where the weights $\omega_{k,c,j,t}$ are computed as the share of capital stock for each intangible capital type k in sector j , over capital stock for intangible capital k in the whole market economy, at time t for country c . The weights are designed to capture the relative importance of each industry within each country. This accounts for the fact that industries with high capital stock endowments relative to the country have a greater overall impact on LPG. Finally, the (time-varying) TFP growth accounting coefficient $GA_{TFP,c,t}$ is instead computed as residual term:

$$GA_{TFP,c,t} = \Gamma'_{LP,c,t} - \sum_{k=1}^7 GA_{k,c,t} \quad (E5)$$

Where $\Gamma'_{LP,c,t}$ is the (weighted) growth rate of labor productivity at time t in country c , computed in an analogous way as in equation (A2). As before, the TFP country-specific single coefficient is then retrieved using equation (A1).

Appendix E. Growth accounting analysis for the EU15

Figure E1. Growth accounting estimates. Market economy, 15 countries.



Note. Computations are based on the 1-digit GMM coefficients presented in Table 3. A comprehensive explanation of the methodology employed can be found in Appendix D.

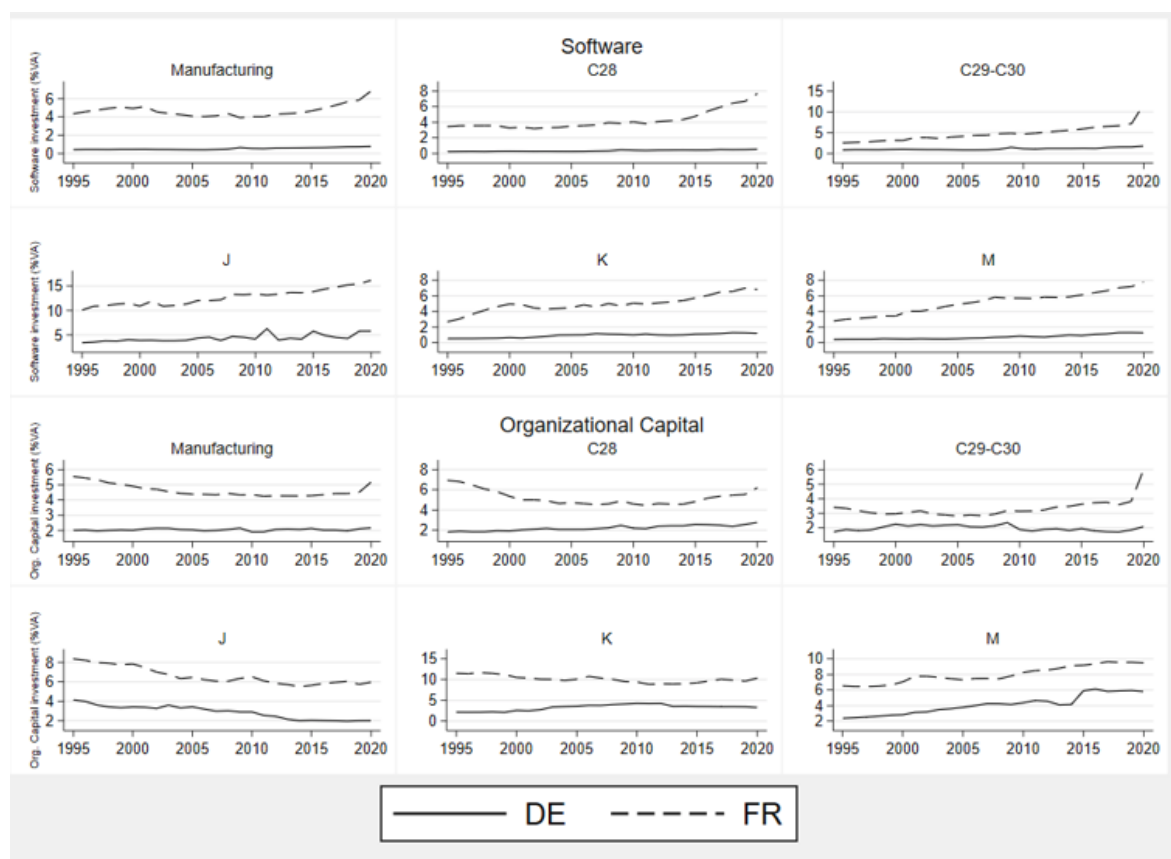
Appendix F. Detailed investments in Software and Organizational Capital, 1995-2020

Table F1. Levels and Ratios of Investments in Software and Organizational Capital across Sectors, France and Germany, average values, 1995-2020

Industry Name	Industry Code	Computer Software & Database			Organizational Capital		
		DE	FR	FR/DE	DE	FR	FR/DE
Agriculture, forestry and fishing	A	0.17	0.06	0.4	0.11	0.79	7.2
Mining and quarrying	B	0.48	3.4	7.1	2.13	3.16	1.5
Manufacturing	C	0.53	4.68	8.8	2.05	4.63	2.3
Manufacture of food products; beverages and tobacco products	C10-C12	0.06	1.18	19.7	2.52	4.45	1.8
Manufacture of textiles, wearing apparel, leather and related products	C13-C15	0.15	3.4	22.7	1.66	4.8	2.9
Manufacture of wood, paper, printing and reproduction	C16-C18	0.08	3.11	38.9	1.98	6.71	3.4
Manufacture of coke and refined petroleum products	C19	0.11	1.4	12.7	2.62	10.59	4
Manufacture of chemicals and chemical products	C20	0.53	2.12	4.0	1.78	3.74	2.1
Chemicals; basic pharmaceutical products	C20-C21	0.88	2.17	2.5	1.62	3.59	2.2
Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	1.66	2.21	1.3	1.28	3.17	2.5
Manufacture of rubber and plastic products and other non-metallic mineral products	C22-C23	0.18	1.86	10.3	1.98	5.4	2.7
Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24-C25	0.13	1.93	14.8	1.82	5.41	3
Manufacture of computer, electronic and optical products	C26	2.21	59.47	26.9	2.88	6.11	2.1
Computer, electronic, optical products; electrical equipment	C26-C27	0.94	30.82	32.8	2.42	4.89	2
Manufacture of electrical equipment	C27	0.33	4.51	13.7	2.14	3.62	1.7
Manufacture of machinery and equipment n.e.c.	C28	0.34	4.23	12.4	2.22	5.22	2.4
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	C29-C30	1.1	4.79	4.4	1.99	3.33	1.7
Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of motor vehicles	C31-C33	0.23	4.15	18.0	1.95	4.1	2.1
Electricity, gas, steam and air conditioning supply	D	0.64	1.27	2.0	1.15	2.41	2.1
Electricity, gas, steam; water supply, sewerage, waste management	D-E	0.48	1.23	2.6	1.15	2.63	2.3
Water supply; sewerage, waste management and remediation activities	E	0.21	1.15	5.5	1.16	3.18	2.7
Construction	F	0.28	0.51	1.8	1.21	4.01	3.3
Wholesale and retail trade; repair of motor vehicles and motorcycles	G	0.76	1.18	1.6	1.43	5.79	4
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	0.53	-	-	1.18	4.3	3.6
Wholesale trade, except of motor vehicles and motorcycles	G46	0.93	-	-	1.39	6.36	4.6
Retail trade, except of motor vehicles and motorcycles	G47	0.65	-	-	1.63	5.56	3.4
Transportation and storage	H	0.44	1.47	3.3	1.16	3.88	3.3
Land transport and transport via pipelines	H49	0.29	-	-	1.14	3.61	3.2
Water transport	H50	0.3	-	-	0.53	19.34	36.5
Air transport	H51	0.57	-	-	0.79	5.03	6.4
Warehousing and support activities for transportation	H52	0.59	-	-	1.12	3.47	3.1
Postal and courier activities	H53	0.51	-	-	1.63	3.89	2.4
Accommodation and food service activities	I	0.4	0.28	0.7	0.4	1.91	4.8
Information and communication	J	4.36	12.71	2.9	2.88	6.61	2.3
Publishing, motion picture, video, television programme production; sound recording, publishing and reproduction of motion pictures on video	J58-J60	6.37	13.41	2.1	2.36	6.3	2.7
Telecommunications	J61	2.91	4.19	1.4	2.84	6.67	2.3
Computer programming, consultancy, and information service activities	J62-J63	3.67	15.26	4.2	3.26	6.47	2
Financial and insurance activities	K	0.92	4.97	5.4	3.31	10.13	3.1
Real estate activities	L	0.04	0.12	3.0	-	0.92	-
Professional, scientific and technical activities	M	0.73	5.12	7.0	4.11	7.99	1.9
Professional, scientific and technical activities; administrative and support service activities	M-N	0.63	3.61	5.7	3.14	6.31	2
Administrative and support service activities	N	0.49	1.44	2.9	1.68	3.91	2.3
Public administration and defence; compulsory social security	O	0.54	1.26	2.3	1.21	1.24	1
Public administration, defence, education, human health and social work activities	O-Q	0.44	0.85	1.9	1.13	1.17	1
Education	P	0.36	0.9	2.5	1.11	1.55	1.4
Human health and social work activities	Q	0.4	0.44	1.1	1.05	0.86	0.8
Human health activities	Q86	0.51	0.38	0.7	0.94	0.79	0.8
Residential care activities and social work activities without accommodation	Q87-Q88	0.11	0.55	5.0	1.34	0.97	0.7
Arts, entertainment and recreation	R	0.33	1.28	3.9	0.81	4.79	5.9
Arts, entertainment, recreation; other services and service activities, etc.	R-S	0.4	2.58	6.5	1.14	4.64	4.1
Other service activities	S	0.44	3.77	8.6	1.32	4.52	3.4
Market economy (all industries excluding L, O, P, Q)	MARKT	0.78	3.35	4.3	2.03	5.27	3.4

Notes: Numbers refer to average values as percentage of value added over the period 1995-2020. Source: Authors' own calculations based on the EUKLEMS/INTANProd 2022 database (Bontadini et al. 2023).

Figure F1. Investments in Software and Organizational Capital in selected Sectors over time, France and Germany, 1995-2020



Source: Authors' own calculations based on the EUKLEMS/INTANProd 2022 database (Bontadini et al. 2023).