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**FAKULTÄT** FÜR WIRTSCHAFTS- UND SOZIALWISSENSCHAFTEN

# Intangible Capital and Firm-Level Productivity – Evidence from Germany

**Felix Roth** 

Ali Sen

**Christian Rammer** 

Hamburg Discussion Paper in International Economics [No.9] University of Hamburg

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# Intangible Capital and Firm-Level Productivity – Evidence from Germany

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#### Abstract

This paper analyses the impact of intangible capital on firm-level productivity for Germany using panel data from the Community Innovation Survey for the time period 2006 to 2018. Our paper presents three novel results. First, we find a highly significant positive relationship between intangible capital and firm-level productivity with elasticities overall in line with previous findings reported for other large EU economies. Second, our results show that both manufacturing and services are highly intangible-capital intensive, and that intangibles have a greater impact on firm-level productivity in services –particular in the business services sector. Third, our results show that intangible capital investments in German firms are equal to investments in tangible capital since the early 2000s. Overall, the evidence presented in our paper indicates that Germany – in line with other advanced economies – has undergone a structural transition into a knowledge economy in which intangibles act as an important driver of firm-level productivity.

Key words: Intangible capital, firm-level productivity, panel data and Germany

JEL classification: D24, O30, L22, C33

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#### 1. Introduction

As highly developed economies advance towards becoming knowledge economies, investments in intangible capital act as key elements of a firm's competitiveness and productivity (Teece 1998, Lev and Radhakrishnan 2005). Although the importance of such knowledge has been long recognized in the management literature (Canibano et al. 2000), economic analyses have developed rather slowly, with a concentration on individual intangible assets, such as software, organizational capital, and R&D – and their mutual interactions (Brynjolfsson and Hitt 2000, Brynjolfsson et al. 2002, O'Mahony and Vecchi 2009, Bloom et al. 2012). The situation gradually changed once scholars started to develop a comprehensive framework of a full set of intangible capital indicators (Nakamura 2001). For example, the seminal work of Corrado et al. (2005) groups knowledge assets of firms into the three categories: i) software, ii) innovative property and iii) economic competencies. This unifying framework has been applied to case studies (e.g. for the US see Corrado et al. 2009, for the UK see Marrano et al. 2009, and for Sweden see e.g. Edquist 2011) and cross-country studies (e.g. for the EU see Roth and Thum 2013) at the macro level as well as at the industry level (e.g. for the UK see Goodridge et al. 2017; for a cross-sectoral study see Niebel et al. 2017).

Only a few applications of this unifying framework of intangibles exist, however, at the firm level. The firm-level work of Marrocu et al. (2011) draws on the Amadeus database of Bureau van Dijk (BvD) for six European economies (France, Italy, the Netherlands, Spain, Sweden, and the UK) for the time period 2002-2006, with a total number of 195,701 firm observations. They show that the impact of intangible capital on productivity is as large as that of tangible capital. Due to data constraints, however, they did not analyze the case of the largest EU and Euro Area country, namely Germany. Moreover, their measure of intangible capital does not fully take into account the unifying framework of intangibles, as it uses the balance sheet category of "intangible fixed assets". The latter does not include assets related to firm-specific human capital (such as training), branding costs (e.g. advertising & marketing) and organization capital or other non-technical knowledge.

Econometric evidence for Germany has until now only focused on the impact of the individual intangible indicators on firm-level productivity (Crass et al. 2014, Rammer and Peters 2016, Kaus et al. 2020). Moreover, these studies have only either differentiated between goods and services (Rammer and Peters 2016) or focused on the manufacturing sector (Kaus et al. 2020). In our study, we close this gap in the research by analyzing the impact of an intangible capital index as well as a complete set of intangible capital indicators on firm-level

productivity for the German economy as a whole, as well as its sub-sectors from the goods and services sectors, using firm-level data from the Mannheim Innovation Panel (MIP) over the 13-year period 2006 to 2018. The MIP is Germany's contribution to the Community Innovation Surveys (CIS) of the European Commission. In contrast to other national CIS, the MIP is an annual panel survey that collects data on expenditures related to intangibles. We estimate a Cobb-Douglas production function at the firm-level by using different econometric estimation methods (Olley-Pakes 1996, Levinsohn-Petrin 2003, and Ackerberg et al. 2015) for around 28,000 firm-level observations from both goods and services sectors.

We find three novel results vis-à-vis the existing literature. First, in line with the empirical evidence for six other EU economies (Marrocu et al. 2011: p. 392), we find a highly significant and positive relationship between intangible capital and firm-level productivity in Germany. The estimated magnitude for our intangible capital index on firm-level productivity for Germany is slightly larger than that found for France and Spain, but smaller than found for Italy and the UK (Marrocu et al. 2011: p. 392).

Second, our results at the sector level suggest that investments in both manufacturing and services are concentrated in intangibles. We also find considerable heterogeneity across industries. More specifically, our results point to a larger impact of intangible capital on firm-level productivity in services compared to manufacturing. Within services, the business services sub-sector (including consulting, engineering and facility management) shows the highest impact of intangibles at the firm-level. Our emphasis on disaggregating the service sector adds value with respect to the recent firm-level productivity analyses for Germany based on production function estimations performed for the total of manufacturing and services (Rammer and Peters 2016) or the manufacturing sector only (Kaus et al. 2020).

Third, our results reveal some striking facts about the dynamics of intangible and tangible capital investments at the firm level. In line with the analysis by Rammer and Peters (2016) for the shorter time period 2006-2014, our data reveal that investments in intangible capital by German firms have been equal to those in tangible capital throughout our 13-year time period from 2006-2018. We show that our micro-evidence contrasts with patterns in intangible capital investments for Germany derived from the industry and macro-level databases such the INNODRIVE (Roth and Thum 2013) and the EU-KLEMS (Stehrer et al. 2019). This calls into question whether intangible capital is being measured validly in these databases, and whether the intangibles that have not been incorporated into the national accounts would need to be constructed from micro-data, as proposed by the GLOBALINTO project (GLOBALINTO 2019). Our findings justify future research along these lines.

This paper is structured as follows. In section 2 we discuss the relevant literature on firmlevel estimations of intangible capital and productivity. Section 3 introduces our empirical model along with a description of the data used in the analysis. Section 4 presents out descriptive results, and while section 5 contains the econometric results. We discuss our results and offer conclusions in the final section.

## 2. Relevant Literature

Most firm-level analyses on the role played by intangibles in productivity focuses on individual dimensions of intangible capital: Battisi et al. (2015) for EU countries, Bontempi and Mairesse (2015) for Italy, Verbic and Polanec (2014) for Slovenia, and Ilmakunnas and Piekkola (2014) for Finland. Among these studies, Verbic and Polanec (2014) consider the role of intangibles for the transition experience of Slovenia and consider three types of intangible capital (organizational capital, R&D, and ICT, the latter of which also includes some tangibles). They conclude that among all types of intangible capital, organizational capital has the greatest impact on a firm's productivity. Examining the experience of firms in their own country from 1998 to 2008, the Finnish academics Ilmakunnas and Piekkola (2014) reach a similar conclusion regarding the role of organizational capital, which is proxied by the proportion of organizational workers, for firm-level productivity. Battisi et al. (2015) consider a panel of European firms to analyze the role of intangibles for productivity. They conclude that intangibles have a considerable effect on both the adoption of advanced technology by the firms and better use of the technologies they already possess. Lastly, for their study of Italian manufacturing firms, Bontempti and Mairesse (2015) find that intellectual capital represented by R&D and patents and consumer capital represented by trademarks and advertising have the highest marginal productivity in their production function estimations.

Conversely, the seminal work by Marrocu et al. (2011) applies the unifying framework for intangibles at the micro level. Marrocu et al. (2011) estimate a firm-level production function for six EU countries (France, Italy, the Netherlands, Spain, Sweden, and United Kingdom) for the period 2002-2006. The aggregate result for these six countries and the individual results for France, Italy, Spain, and the UK are shown in Table 1. They consider the effects of both individual intangible capital owned by the firm and external knowledge available to them, which are proxied by human capital, technological capital, and public capital available to a firm in its region. They find a sizeable and statistically significant effect for intangible capital on real value added. Due to data constraints, however, they did not analyze the case of the largest EU and Euro Area country, Germany. Moreover, their measure of intangible capital does not fully take into account the unifying framework of intangibles, as it uses the balance sheet category of "intangible fixed assets". This category includes the net value of capitalized expenditure for only some intangibles: parts of in-house R&D and in-house software expenditure as long as an amortization period can be established, purchase of patents, trademarks and other industrial rights, purchase of licenses and software), while it also includes some items that are not part of the unifying framework of intangibles (acquired customer relationships, acquired company values). The balance sheet category of intangible assets does not include assets related to firm-specific human capital (such as training), branding costs (e.g. advertising) organization capital or other non-technical knowledge. We complement their work by concentrating upon Germany: To this end we apply a coherent intangible capital index consistent with their unifying framework and use data from the Mannheim Innovation Panel for the 13-year time period 2006-2018.

Table 1: Impact of Intangible Capital on Real Value Added

	Aggregate	France	Italy	Spain	UK
Intangible Capital	0.038***	0.030***	0.051***	0.023***	0.081***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.004)
Observations	195,701	51,248	78,324	57,631	9,989

**Notes:** Coefficients are based on Olley and Pakes (2006) estimator. Standard errors in parantheses. \*p < 0.10, \*\*p < 0.05, \*\*\*p < 0.01

Source: Marrocu et al. (2011).

While no study that utilizes an intangible capital index in line with the unifying framework as developed by Nakamura (2001) and Corrado et al. (2005) exists for Germany, three recent studies analyze the effects of individual intangible assets on the productivity of German firms: Crass and Peters (2014), Rammer and Peters (2016), and Kaus et al. (2020). Their results are summarized in Table 2. While Crass and Peters (2014) and Rammer and Peters (2016) use data from the Mannheim Innovation Panel (MIP), Kaus et al. (2020) rely on a variety of surveys (investment, cost structure, monthly and quarterly production) from business statistics of the Federal Statistical Office of Germany.

	(1)	(2)	(3)
	Crass and Peters (2014)	Rammer and Peters (2016)	Kaus et al. (2020)
Dependent Variable	Labour Productivity	Labour Productivity	Gross Output, Value Added
Intangible Capital*	-	-	0.013***
R&D	0.033***	0.043***	0.017***
Design & Licenses	0.005*	0	-
Patent Stock	0.004	0	0.001
Training	0.044***	0.036***	-
High-Skilled Labor	0.263***	0.234***	-
Advertising & Marketing	0.034***	0.058***	-
Trademark Stock	0.025***	-	-
Software	-	0.034***	0.008***
Observations (Software)	11,021	17,804 (8,198)	95,638
Aggregation Level	Market Economy	Market Economy	Manufacturing
Time Period	2006-2010	2006-2014	1995-2016
Data Set	MIP	MIP	Several surveys
Estimation Method	OP	OP	OLS, Wooldridge (2009)
*** < 0.05 **** < 0.01 *****	< 0.001		

#### Table 2: Results of firm-level studies on intangibles in Germany

p < 0.05, p < 0.01, p < 0.01

**Notes:** ‡ Intangible capital only consists of indicators from: i) software and ii) innovative property, but it does not incorporate iii) economic competencies. OP refers to Olley and Pakes (2006); MIP refers to the Mannheim Innovation Panel.

Crass and Peters (2014) study the impact of R&D, design and licenses, patent stock, training, high-skilled labour, and advertising & marketing, based on 11,021 firm observations for the time period 2006-2010, utilizing an Olley and Pakes (2006) estimation approach. An updated econometric estimation is performed by Rammer and Peters (2016) for the time period 2006-2014 based on 17,804 observations. In contrast to Crass and Peters (2014), they also include software as an additional intangible capital indicator. Both studies find that intangibles related to economic competencies (advertising & marketing and training) have the greatest impact on the firm-level labour productivity. Intangible capital related to innovative property also positively contributes to firm-level productivity, but on a smaller magnitude. Kaus et al. (2020) consider the role of intangible capital for productivity of 95,638 manufacturing firms. They combine different firm-level data sources and cover intangibles related to software and innovative property but do not include economic competencies. Their analysis of manufacturing firms concludes that R&D has the greatest output elasticity among different intangible capital types, followed by a lesser extent by software.

In the studies that include both computerized information and innovative property (Rammer and Peters 2016, Kaus et al. 2020), innovative property turns out be more important than computerized information for firm-level productivity. Interestingly, none of these three studies finds a significant impact of patent stock on productivity, which suggests that the

positive impact of patent stock on productivity found in other studies (Griliches 1984, Bloom and van Reenen 2002) may be due to the absence of other intangible capital types.

We complement these three studies by i) using an extended time period 2006 to 2018, ii) employing both an intangible capital index and five individual intangible capital indicators from all three dimensions of the unifying framework, and iii) analyzing heterogenous effects of intangible capital on firm-level productivity across goods and services and within services. Analyzing the link between intangibles and firm-level productivity in the service sector is particularly relevant given both the sheer size of this sector (accounting for 75% of total employment in Germany, as of 2020) and the large productivity differences found across service industries (Duarte and Restuccia 2019, Duernecker et al. 2019).

Our work is also related to the literature that explores the rise of intangible capital and its effects on the aggregate economy as exemplified by McGrattan and Prescott (2010, 2014), Holmes et al. (2015) and Koh et al. (2020). For the US, Nakamura (2010) shows that business investments in intangible capital already surpass investments in tangible capital after year 2000. We would normally expect that Germany as an advanced economy follows a pattern similar to that seen in the US. As can be seen in Table 3, however, selected *econometric* papers using the existing sectoral and macro-level databases on intangible capital assets from the INNODRIVE (Roth and Thum 2013), INDICSER (Niebel et al. 2017), INTAN-Invest (Roth 2020), and EU-KLEMS (Stehrer et al. 2019) projects still identify Germany as an economy that is rather dominated by tangible capital [as exemplified by the Ratio of Intangible Capital over Tangible Capital (RITC) which is below 0.70]. Rammer and Peters (2016) demonstrate that German firms invest more in intangible capital than in tangible capital; we complement their work by extending the time period from 2006 to2018. Our firm-level-based evidence suggests an aggregate intangible investment rate greater than those of the existing industry-level and macro databases, even though we do not account for relatively sizeable organizational capital.

	Investment Rate for Intangible Capital (% of GVA)	Investment Rate for Tangible Capital (% of GVA)	Ratio of Intangible Capital over Tangible Capital	Time Period
INNODRIVE (Roth and Thum 2013)	9.22	14.50	0.64*	1995-2005
INDICSER (Niebel et al. 2017)	7.15	14.42	0.50*	1995-2007
INTAN-Invest (Roth 2020)	9.14	13.77	0.66*	1995-2017
EU-KLEMS (Stehrer et al. 2019)	7.23	13.77	0.53	1995-2017

Table 3: Investment Rates for Intangible and Tangible Capital and their Ratios

**Note**: \*Since these databases do not contain any information on tangible capital, the ratio of intangible capital over tangible capital is obtained by using the tangible investment rate from the 2019 EU-KLEMS release (Stehrer et al. 2019).

# 3. Model Specification, Data, and Research Design

#### 3.1 Model Specification

We consider the following production function at the firm-level:

$$Y_{i,t} = A_{i,t} M^{\theta}_{i,t} K^{\alpha}_{i,t} L^{\beta}_{i,t} R^{\gamma}_{i,t}$$

$$\tag{1}$$

where  $Y_{i,t}$  denotes the gross output,  $A_{i,t}$  the total factor productivity,  $M_{i,t}$  the intermediate inputs,  $K_{i,t}$  the physical capital,  $L_{i,t}$  labor, and  $R_{i,t}$  the intangible capital. We consider a standard production function apart from the inclusion of the intangible capital. We do not put any restrictions on the elasticity parameters  $\theta$ ,  $\alpha$ ,  $\beta$ ,  $\gamma$  *a*. In the case of  $\theta + \alpha + \beta + \gamma = 1$  our functional form reduces to the well-known Cobb-Douglas case. In relation to Marrocu et al. (2011), who estimate a value-added specification with regional controls, we consider a grossoutput production function more in line with the firm-level studies on productivity as exemplified by Olley and Pakes (1996) and Levinsohn and Petrin (2001). Apart from these differences, our preferred model specification is comparable to theirs.

The form we chose for the production function is well grounded in neoclassical theory, and it could be considered as an intangible capital augmented version of the standard neoclassical production function used recently in such works as Koh et al. (2020), McGrattan and Prescott (2010, 2014), and Holmes et al. (2015). In this regard, accommodating intangible capital to an otherwise standard production function could be considered as an attempt to better measure inputs; and therefore, as argued by Jorgenson and Griliches (1967), the role of TFP in explaining productivity will also diminish. When we log-normalize the equation 1, we get the following equation (where the lower-case variables indicate the log-normalized values):

$$y_{i,t} = a_{i,t} + \theta m_{i,t} + \alpha k_{i,t} + \beta l_{i,t} + \gamma r_{i,t}$$

$$\tag{2}$$

We also assume that the productivity term  $a_{i,t}$  consists of an industry-specific effect  $a_i$ , a timespecific effect  $a_t$ , a vector of control variables  $x_{i,t}$  which include a dummy for East Germany, a dummy for whether a firm is part of an enterprise group, a dummy for whether a firm is an exporter, and an error term  $\varepsilon_{i,t}$  which satisfies the standard properties:

$$a_{i,t} = a_i + x_{i,t} + a_t + \varepsilon_{i,t} \tag{3}$$

Inserting equation (3) into equation (2) yields the following equation (4):

$$y_{i,t} = a_i + a_t + \theta m_{i,t} + \alpha k_{i,t} + \beta l_{i,t} + \gamma r_{i,t} + x_{i,t} + \varepsilon_{i,t}$$

$$\tag{4}$$

#### 3.2 Data

Our paper uses data from the Mannheim Innovation Panel (MIP) covering the period 2006-2018. The MIP is Germany's contribution to the Community Innovation Surveys (CIS) of the European Commission. Unlike most national CIS, the MIP is an annual panel survey based on a stratified random sample of firms, which is updated every other year to adjust for panel mortality (see Peters and Rammer 2016 for more details). Another important difference is that the MIP also includes a number of questions on financial variables, including expenditures related to different types of intangibles (training, advertising & marketing, software & databases, research & development and other innovation expenditure) as well as sales, labour costs and cost of intermediary inputs. In addition, it covers a wider set of services industries (i.e. most services of Nace sections M and N) and size classes (i.e. also 5 to 9 employees) than those included in the CIS. The MIP has been conducted by the Centre for European Economic Research (ZEW) in Mannheim on behalf of the German Federal Ministry of Education and Research since 1993. As the MIP is the input for the CIS, it is subject to rigorous quality controls and represents the most reliable and comprehensive data base on innovation-related activities in German firms.

The data utilized within our descriptive and econometric analysis consist of the following elements:

- The gross output variable is measured as total turnover in millions of euros.
- The labour variable refers to the total number of employees in full-time equivalents.
- The intermediate inputs are measured as the total costs of purchased materials, energy, and services.
- The physical capital stock is obtained from a questionnaire on the net stock of fixed assets, imputing some missing values based on data on investments in physical capital.
- Intangible capital is measured as an index which combines all three main categories of: i) computerized information, ii) innovative property and iii) economic competencies. It is obtained by totaling investments in all these intangible types.
- Computerized information is measured by the software & databases expenditures (only available from 2011 onward). Innovative property consists of Research & Development (R&D) and other innovation expenditure (e.g. design & licenses). Economic competencies are measured by advertising & marketing and training expenditures.<sup>4</sup>

Table 4 provides the summary statistics for our firm-level evidence. From this table we observe that the distributions of the firm-level variables are highly-skewed, reflecting a few very large firms in the sample. This rightly-skewed distribution of intangible investments is also noted by Kaus et al. (2020) in their study on manufacturing firms, and it is well known that firm-level aggregates are in general characterized by Pareto distributions (Gabaix 2011).

<sup>&</sup>lt;sup>4</sup> Our set of intangibles indicators is missing one category of the unifying framework: organization capital. The MIP survey only collects qualitative information on this category. Attempts to measure expenditure related to organization capital failed due to lack of information on the side of firms. Using data from the MIP survey, organization capital is actually calculated with the help of a residual estimation approach (seeTrunschke et al. 2020).

	Mean	Median	Min	Max	CV	SD	Ν
Gross Output	180	4.4	0	76729	10	1798	29334
Labor*	549	35	1	183991	8	4526	29334
Materials	114	1.3	0	61167	11	1297	29334
Tangible Capital	106	0.7	0	55630	12	1288	29334
Intangible Capital	11.32	0	0	8126	15	164	29334
R&D	8	0	0	5800	15	113	29334
Design & Licenses	2	0	0	1015	14	20	29334
Training	0.4	0	0	350	11	5	29334
Advertising & Marketing	1.9	0.01	0	1495	19	36	29334
Software**	1	0	0	665	12	13	18261

**Table 4:** Summary Statistics for Firm-Level Evidence, 2006 to 2018

**Notes:** \*All values are expressed in millions of euro, except Labor. \*\* Summary statistics for Software cover only the period 2011 to 2018.

Data source: Mannheim Innovation Panel (MIP).

# 4. Descriptive Results

This section summarizes the descriptive results on the development of intangible investment in the market economy sector in Germany. The data are derived from extrapolations of the MIP firm-level data to industries and economy totals, complemented by data from German national accounts statistics at the industry level. The extrapolations of MIP data on intangibles apply the same methods used for producing aggregate innovation indicators for European innovation statistics. As the weighting scheme is based on data from the official German business register, the data are fully comparable with data from other business statistics.



Figure 1: Tangible and Intangible Investments in Germany, 2006 to 2018

**Notes:** \* Research & Development (R&D) includes extramural R&D and expenditure for software development as part of R&D activities. \*\* Software excludes software development as part of R&D activities. \*\*\* Estimates for 2015 to 2017. \*\*\*\* Following Landes and Rosenfield (1994), only 60 percent of the actual expenditure on advertising & marketing was considered investment. \*\*\*\* Data collected for 2012 only. The ratio above each bar represents the ratio of intangible over tangible capital investments (RITC). **Data source:** Mannheim Innovation Panel (MIP).

Figure 1 provides a breakdown of tangible and intangible investments for 2006 to 2018. The figure shows that intangible capital investments are equal to tangible capital investments in the period considered (denoted in the remainder of this paper as the ratio of intangible over tangible capital investments as RITC). This equal ratio of intangible investments over tangibles is consistent with the evidence from other advanced economies such as the US and the UK (see here Nakamura 2010). Among the different types of intangible investments, R&D accounts for the largest share followed by advertising & marketing expenditures, while software, other IPRs, design & licenses and training investments have lower shares. Figure 2 shows the overall aggregate investment rates for the market economy in Germany from 2006 to 2018. These numbers suggest an average 22.1% investment rate for Germany during this period, in which intangible and tangible capital investments contributed equally.



Figure 2: Investment Rates for the Market Economy in Germany, 2006-2018

Data source: Mannheim Innovation Panel (MIP).

Both Figures 1 and 2 offer different empirical evidence as derived from the existing international industry- and macro-level datasets that provide statistics about tangible and intangible capital. According to selected *econometric* papers using the existing sectoral and macro-level databases on intangible capital assets from the INNODRIVE (Roth and Thum 2013), INDICSER (Niebel et al. 2017), INTAN-Invest (Roth 2020) and EU-KLEMS (Stehrer et al. 2019) projects, the estimations made in these studies show that intangible investments are generally less than 10% of GDP even when organizational capital is included, and therefore the RITC is well below 1 (see here also Table 3 and Figure A1 in the Appendix). Table 5 gives more details about the sources of this discrepancy between MIP and KLEMS databases. The higher intangible investment rate based on MIP data is largely due to higher investment rates in advertising & marketing with respect to the KLEMS data. This result is plausible as the MIP data also include the firms' in-house expenditure on development marketing strategies and brand value whereas KLEMS data mainly reflect purchased services for enhancing brand value. Higher values are also reported for R&D (which partly reflect the fact that software expenditures in the context of R&D are reported under R&D and not software), design and licenses, other IPRs, and training.

**Table 5**: Intangible Capital Investments as a Share of Value Added in Germany, 2006-2017,by Type of Intangible Capital: KLEMS vs. MIP

	Total	R&D*	D&L	A&M**	S&D	OIPR	Training
KLEMS	8.06	4.08	1.27	0.89	1.29	0.31	0.22
MIP	11.04	4.80	1.51	2.32	1.23	0.58	0.59

**Notes:** R&D: Research and Development; D&L: Design and Licenses; A&M: Advertizing & Marketing; S&D: Software and Databases; OIPR: Other Intellectual Property Rights.

\* Only intramural R&D expenditure for both KLEMS and MIP.

\*\* Following Landes and Rosenfield (1994), only 60 percent of the actual expenditure on Advertising & Marketing in the MIP was considered investment.

Data source: EUKLEMS and Mannheim Innovation Panel (MIP).

Figure 3 shows the evolution of tangible and intangible investment over the 13-year period 2006 to 2018. The figure reveals that some investments in intangible capital, notably R&D, grew faster than tangible capital. However, tangible capital still ranks as the second with a similar trend to software, but faster than other investments in intangible capital, such as training and advertising & marketing. Investments in tangible capital are accelerating from 2013 onward.



Figure 3: Evolution of Tangible and Intangible Investment in Germany, 2006-2018

**Notes:** \* R&D includes extramural R&D and expenditure for software development as part of R&D activities. \*\* Software excludes software development as part of R&D activities; \*\*\* Estimates only for Design & Licenses for period 2015-2017.

Data source: Mannheim Innovation Panel (MIP).

Figure 4 provides a breakdown of capital investment by types across disaggregated manufacturing industries and displays an intangible/tangible capital ratio (RITC). Strikingly, we detect that intangible capital investments, driven largely by R&D, well exceed tangible capital investments in certain manufacturing industries. This is particularly the case for Electronics, Electrical Equipment (RITC=2.92); Machinery and Equipment (RITC=1.66); and Vehicles (RITC=2.12). These facts are in line with the existing firm-level studies on Germany such as Crass and Peters (2014), Rammer and Peters (2016) and Kaus et al. (2020). It is interesting to observe a high ratio of intangible capital investments in even low-tech manufacturing industries such as Textiles, clothing, leather (RITC=1.65), driven in particular by advertising & marketing investments in these industries.





Notes: The figure refers to values in year 2018. Chemicals, pharmac., petrol. prod. = Chemicals, pharmaceuticals, petroleum products. \*R&D includes extramural R&D and expenditure for software development as part of R&D development activities. \*\* Software excludes software as part of R&D activities. Values on the right-hand side of the figure display the ratio pf intangible over tangible capital (RITC). Following Landes and Rosenfield (1994), only 60 percent of the actual expenditure on advertising & marketing was considered investment. Data source: Mannheim Innovation Panel (MIP).

Figure 5 shows the investments in tangible and intangible capital for service industries. In relation to the composition of investment, the figure suggests a considerable heterogeneity within services. On the one hand, we observe highly tangible capital-intensive industries such as Wholesale Trade (RITC=0.46) and Transportation and Storage (RITC=0.08). These service industries co-exist with other industries such as advertising and other professional services (RITC=8.60) and Publishing, film, and broadcasting (RITC=5.36), where tangible capital only

makes up a minor share of total investments. Although the dominance of R&D is clear in the case of manufacturing industries, service industries show somewhat heterogeneous patterns with no single intangible capital type dominating investments over different service industries. Although some other studies also considered the investment composition of service industries (for example, Rammer and Peters 2016), to the best of our knowledge they do not emphasize the heterogeneous character of intangible investments within services and have not displayed the RITCs systematically.



Figure 5: Investments in Tangible and Intangible Capital, Services Industries, 2018

**Notes:** The figure refers to values in year 2018.disp. = disposal; account. = accounting; manag = managerial; prof.. = professional; Empm. serv. = Employment services; ag. = agencies; oth. business supp. = other business support. \* R&D includes extramural R&D and expenditure for software development as part of R&D activities. \*\* Software & Databases exclude software development as part of R&D activities. Values on the right-hand side of the figure display the ratios of intangible over tangible capital (RITC). Following Landes and Rosenfield (1994), only 60 percent of the actual expenditure on Advertising & Marketing was considered investment.

Data source: Mannheim Innovation Panel (MIP).

# 5. Econometric results

For estimating firm-level production functions as conceptualized in equation 4, we use the estimation methods developed by Olley and Pakes (1996), Levinsohn and Petrin (2003), and Ackerberg et al. (2015). A well-known problem of estimating firm-level production functions is endogeneity: When a firm is hit by a positive/negative productivity shock, this will also affect its input decisions. This fact makes the OLS estimators biased and inconsistent. The

Olley-Pakes (OP) estimation overcomes the endogeneity problem by replacing the productivity term with a semi-parametric function of investment which approximates the changes in productivity. Although this is a well-established approach, it is still afflicted by certain empirical problems: In the real world, not all firms invest. This fact makes the monotonicity assumption required for the identification in the OP approach untenable. The Levinsohn-Petrin (LP) approach overcomes this problem by using intermediate input expenditures at the firm-level as proxies for productivity. The last estimator we consider in this study, Ackerberg et al. (2015), solves the collinearity problem that may affect OP and LP estimation methods when free variables do not vary independently from the proxy variable. This is largely an issue for the identification of labour input in the production function.

Our estimation results of equation 4 are shown in Table 6. Utilizing almost 27,000 observations from 2006-2018, the results of our OP and LP estimations suggest an elasticity value of 0.024 and 0.025, respectively, for our intangible capital index. In value-added terms, these values correspond to an elasticity parameter that is equal to 0.037 (OP), 0.033 (LP) and 0.046 for ACF.<sup>5</sup> Our OP value is slightly smaller than the one found by Marrocu et al. (2011), who report an LP for their aggregated value of 0.056. As can be inferred from Table 1, however, our LP value is strongly in line with the aggregated value one found by Marrocu et al. (2011), who report a LP value of 0.038. How does our LP value compare to the individual country estimations in Marrocu et al. (2011)? As can be inferred from Table 1, our LP estimation for Germany is larger than that for France and Spain, but significantly smaller than that for Italy or the UK.

When we include software, which is only available in the MIP after 2011, with an overall number of observations of more than 16,000 to our intangible capital aggregator, we observe that the elasticity of intangible capital increases by 0.008 for the OP and by 0.007 for the LP to 0.032. These elasticities in gross output production function correspond to an elasticity of 0.049 for the OP, and it suggests an elasticity value of 0.040 for the LP in value-added terms. Considering that ACF (Ackerberg, Caves, and Frazer, 2015) suggest an elasticity of 0.055 for the value-added production function, we can conclude that our econometric estimates suggest an elasticity value around 0.040-0.055 for intangible capital in Germany.

<sup>&</sup>lt;sup>5</sup> These numbers are obtained by dividing the elasticity we find for the intangible capital by the elasticity of value added which equals to 1-the elasticity of materials. That is, the number for OP is obtained by the following equation: 0.037 = [0.024/(1-0.363)] and that for LP by the following equation: 0.033 = [0.025/(1-0.251)].

Our three control variables indicate that firms that are exporters and belong to an enterprise group have higher firm-level productivity. East German firms have lower firm-level productivity.

	OP	LP	ACF
(2006-2018)			
Labor	0.485***	0.491***	0.746***
	(110.72)	(117.44)	(155.42)
Materials	0.363***	0.251***	-
	(77.06)	(23.85)	-
Tangible Capital	0.053***	0.082***	0.114***
	(4.48)	(3.65)	(10.37)
Intangible Capital	0.024***	0.025***	0.046***
	(57.14)	(12.68)	(5.05)
Controls			
Export	0.068***	0.056*	0.107***
-	(13.23)	(2.40)	(11.33)
East Germany	-0.160***	-0.168***	-0.224***
-	(-50.43)	(-7.98)	(-41.66)
Group	0.154***	0.166***	0.172***
	(5.40)	(10.11)	(8.78)
Observations	23157	26794	26737
(2011-2018)			
Labor	0.489***	0.499***	0.744***
	(43.83)	(81.54)	(263.42)
Materials	0.353***	0.206***	-
	(47.01)	(4.90)	-
Tangible Capital	0.053***	0.069**	0.097***
	(3.34)	(7.16)	(9.99)
Intangible Capital	0.032***	0.032***	0.055***
(including Software, 2011-2018)	(11.00)	(25.12)	(9.04)
Controls			
Export	0.063***	0.088***	0.100***
	(6.56)	(8.14)	(51.69)
East Germany	-0.143***	-0.134***	-0.196***
	(-15.12)	(-11.16)	(-78.42)
Group	0.176***	0.155***	0.178***
	(32.13)	(10.56)	(67.98)
Observations	14085	16726	16694

Table 6: Firm-Level Production Function Estimates: Germany, 2006-2018

**Notes**: T-statistics are in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industry- and time-specific effects. OP refers to the Olley-Pakes (1996) estimation method; LP, Levinsohn-Petrin (2003) and ACF, Ackerberg, Caves, and Frazer (2015). The results on the column of ACF refer to value added production function.

Data source: Mannheim Innovation Panel (MIP)

In order to understand the underlying sectoral dynamics, we distinguish in Table 7 the firm-level production function across two broad sectors of the economy: goods and services. Our results suggest that services are more tangible capital-intensive than goods. The results of the LP, our preferred estimation method, suggest that the elasticity of intangible capital in services is more than two times the elasticity found for goods. Since services makes up a large and increasing share in the aggregate economy, we expect that intangible capital will become more important in the aggregate economy over time.

		Goods			Services	
	OP	LP	ACF	OP	LP	ACF
Labor	0.393***	0.415***	0.714***	0.541***	0.553***	0.747***
	(181.62)	(51.48)	(625.71)	(33.40)	(42.85)	(127.22)
Materials	0.451***	0.300***	-	0.288***	0.160***	-
	(42.29)	(4.12)	-	(53.80)	(8.91)	-
Tangible Capital	0.0192**	0.037	0.119***	0.060***	0.067**	0.073***
	(2.65)	(1.63)	(20.79)	(3.35)	(3.26)	(13.94)
Intangible Capital	0.019***	0.022***	0.044***	0.051***	0.046***	0.057***
(including Software)	(8.66)	(9.07)	(14.94)	(10.22)	(19.75)	(5.54)
Controls						
Export	0.059***	0.061*	0.079***	0.103***	0.126***	0.131***
-	(16.15)	(2.28)	(101.25)	(26.90)	(4.53)	(30.24)
East Germany	-0.125***	-0.158***	-0.182***	-0.208***	-0.200***	-0.209***
-	(-134.42)	(-16.04)	(-216.64)	(-9.95)	(-15.37)	(-70.70)
Group	0.160***	0.158***	0.153***	0.154***	0.185***	0.194***
	(26.88)	(9.29)	(71.85)	(4.62)	(27.07)	(22.34)
Observations	8907	10229	10205	5178	6497	6489

**Table 7:** Firm-Level Production Function Estimations for Goods and Services, 2011-2018

**Notes**: T-statistics are in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industry- and time-specific effects. OP refers to the Olley and Pakes (1996) estimation method; LP, Levinsohn-Petrin (2003) and ACF, Ackerberg, Caves, and Frazer (2015). The results in the column of ACF refer to value added production function.

Data source: Mannheim Innovation Panel (MIP).

Given the importance of the service sector in the economy and the well-known fact that it consists of highly heterogeneous sub-units in terms of productivity, we also performed estimations for different service industries. The results shown in Table 8 confirm the heterogeneous character of services in terms of intangible capital intensity. With a value of 0.050, business services, with a high-intangible capital intensity, co-exists with less intangible capital services industries such as wholesale and retail trade. It is important to note that this highly intangible capital-intensive sub-sector has an increasing share within services (Miles et al. 2018). As can be detected from Table 2, our LP value of 0.022 for manufacturing is almost double compared to the OLS value of 0.013 found in Kaus et al. (2020). Although this difference could reflect the use of different estimation methods, it could also be the case that our measure for intangible capital also includes economic competencies that are omitted in Kaus et al. (2020).

	Manufacturing	Wholesale and Retail Trade	Transportation and Storage	Information and Communication	Finance	Business Services
Intangible Capital	0.022***	0.025*	0.024	0.025***	0.023	0.050***
(including Software)	(12.66)	(2.14)	(1.74)	(2.82)	(0.74)	(8.66)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7978	817	1013	1066	379	3174

 Table 8: Intangible Capital Elasticity across Disaggregated Sectors: Germany, 2011-2018

**Notes**: T-Statistics in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industryand time-specific effects. Our data source is the MIP. The reported values refer to LP estimation results. **Data source**: Mannheim Innovation Panel (MIP).

To further analyze the impact of intangibles on the productivity of German firms within manufacturing, we separate this sector into three groups according to their technological intensities (high-tech, medium-tech and low-tech, following a standard classification of the OECD; see Galindo-Rueda and Verger, 2016) and estimate separate production functions for each group. Table 9 reports the results of this exercise. Although high-tech manufacturing has the largest intangible capital elasticity among different manufacturing industries, as we would expect, low-tech has a higher elasticity than low-tech manufacturing. We hypothesize that the high advertising & marketing investment share we noticed for low-technology manufacturing in the previous section (see Figure 4) could stand behind this result.

	High-Tech Manufacturing	Mid-Tech Manufacturing	Low-Tech Manufacturing
Intangible Capital	0.036***	0.015***	0.017***
(including Software)	(5.81)	(9.76)	(6.50)
Controls	Yes	Yes	Yes
Observations	2964	2605	1013

**Table 9:** Intangible Capital Elasticity across Manufacturing Industries: Germany, 2011-2018

**Notes**: T-statistics in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industryand time-specific effects. The reported values refer to LP estimation results. **Data source**: Mannheim Innovation Panel (MIP).

To better understand the role of the individual intangible capital indicators, in particular economic competencies for the productivity performance of German firms, Table 10 reports the results for the specification that disaggregates intangible capital across five distinct categories: R&D, design & licenses, training, advertising & marketing, and software. Among these five distinct categories we can consider that R&D and design & licenses correspond to innovative property, while training and advertising & marketing represent economic competencies, and finally software represents computerized information. Our results show that training has the greatest impact on firm-level productivity, followed by software and advertising & marketing. We interpret this result to be supportive of Brynjolfsson et al. (2002), where they argue that intangible assets such as organizational design and worker training are complementary to ICT equipment and that firms will only reap productivity benefits from the ICT investments if they also make these necessary investments in intangible assets.<sup>6</sup> In relation to the firm-level studies that focus on Germany and use the MIP database (Crass and Peters 2014 and Rammer and Peters 2016), our ranking of the importance of the individual intangible capital indicators is distinct from them. The find that advertisement & marketing has the greatest effect on firm-level productivity, followed by research & development, training and software. We think that these differences between our study and other firm-level studies that use the MIP regarding the individual intangible types is related to the fact that these studies estimate labour productivity instead of gross-output and include patent stock as an independent variable in their regressions.<sup>7</sup> In addition, our research design utilizes an extended time frame

<sup>&</sup>lt;sup>6</sup> They also stress the importance of organizational capital investments, which we cannot include in our classification of economic competencies because of the measurement problems we reported above.

<sup>&</sup>lt;sup>7</sup> It should be stressed that once estimating our production function for labor productivity (gross output / labor) instead of gross output, our intangible capital coefficient increases in magnitude and reaches a level of magnitude for training and software similar to both Crass and Peters (2014) and Rammer and Peters (2016). Estimation results when estimating labor productivity can be obtained from the authors upon request.

with a significantly higher number of 14,085 vs. 8,198 overall observations for our OP estimation (see Table 2).

Table 1	<b>0:</b> Production	Function	Estimation	Results	for I	Disaggregated	Intangibles:	Germany
2006-20	18							

	OP	LP	ACF
Labor	0.481***	0.486***	0.737***
	(97.76)	(106.01)	(399.94)
Materials	0.362***	0.269***	-
	(77.12)	(41.40)	-
Research & Development	-0.001	0.000	0.015***
	(-1.03)	(0.05)	(49.27)
Design & Licenses	0.001	0.000	0.002*
	(1.14)	(0.41)	(8.46)
Training	0.016***	0.019***	0.036***
	(13.55)	(26.64)	(34.92)
Advertising & Marketing	0.009***	0.009***	0.020***
	(11.31)	(7.45)	(54.22)
Tangible Capital	0.055***	0.086***	0.113***
	(5.48)	(5.34)	(433.50)
Controls			
Export	0.081***	0.095***	0.116***
	(8.82)	(3.64)	(197.88)
East Germany	-0.155***	-0.158***	-0.222***
-	(-45.17)	(-6.76)	(-175.92)
Group	0.156***	0.181***	0.170***
	(16.63)	(9.87)	(149.91)
Observations	23157	26794	26737
Software (2011-2018)	0.010***	0.011***	0.028***
	(19.60)	(16.60)	(5.04)
Observations	14085	16726	16694

**Notes**: T-statistics in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industryand time-specific effects. The results in the column of ACF refer to the value-added production function. **Data source**: Mannheim Innovation Panel (MIP).

Table 11 analyses the impact of our five intangible capital indicators on firm productivity performance for the goods, services, manufacturing and five service industries. For goods and services we find that computerised information, such as software and economic comepetencies such as training and advertising & marketing have a positive impact on productivity. However, the elasticities of these three intangible indicators in services is 1.5 to almost 3 times larger than in goods. In relation to Rammer and Peters (2016), we find an insignificant relationship between research & development and firm-level productivity for both

goods and services. For economic competencies-type intangibles, the ranking of the importance of the individual intangible capital indicators is distinct in the goods sector but in line with their results for the services sector. In relation to Kaus et al. (2020), our results for manufacturing indicate a significantly lower elasticity for R&D, which is only statistical significance at the 10 percent confidence interval, while we find a similar elasticity of software on firm-level productivity.

Our analysis for the five service industries shows that both high-intensive (business services and information & communication services) as well as low-intensive market services sub-sectors (transportation and storage, and wholesale and retail trade) benefit from investments in economic competencies. For example, while highly significant and large magnitudes concerning training are driven by business services, transportation and storage sub-sectors. We view these results as supportive of the hypohesis advanced by van Ark et al. (2008) and Timmer et al. (2010): namely, that the productivity gap of the EU's market services with respect to the US could be related to a lower intangible investment rate in the EU. Our results for Germany suggest that in particular low investments in economic competencies could stand behind this result.

Since the existing firm-level studies for Germany do not provide estimation results for disagregated service subsectors, it is not possible to compare our results with theirs. We believe that by providing micro evidence for these services' sub-sectors we take a first step in understanding what determines productivity in them. Our firm-level evidence suggests that intangibles play a pivotal role in determining the productivity of these sub-sectors, and these results should be taken into account along with the high importance of these sub-sectors to aggregate productivity, as shown by van Ark et al. (2008). To the best of our knowledge, our study is the first to provide micro-evidence on the intangible capital determinants of productivity in these services subsectors.

**Table 11:** Production Function Estimation Results for Disaggregated Intangibles across

 Sectors: Germany, 2011-2018

	Goods	Services	Manuf.	Wholesale, Retail Trade	Transportation and Storage	ICT	Finance	Business Services
Labor	0.412***	0.547***	0.407***	0.565***	0.498***	0.638***	0.816***	0.827***
	(53.37)	(44.56)	(30.77)	(22.00)	(11.36)	(27.59)	(14.04)	(65.92)
Materials	0.303***	0.157	0.464***	0.153***	0.252***	0.137***	0.072***	0.170***
	(4.76)	(10.29)	(4.85)	(2.71)	(10.92)	(5.92)	(2.89)	(5.54)
Tangible Capital	0.043	0.059***	0.066***	0.049***	0.030	0.137***	0.099	0.061***
	(1.86)	(12.58)	(13.16)	(3.96)	(0.95)	(3.95)	(1.86)	(6.72)
Research & Development	0.000	0.000	0.001	-0.001	0.004	0.002	0.022**	-0.002
	(0.10)	(0.35)	(1.92)	(-0.19)	(0.34)	(1.31)	(2.75)	(-0.93)
Design & Licenses	0.000	0.002*	0.000	0.002	0.003	0.004	-0.005	- 0.004***
	(0.07)	(2.37)	(1.59)	(0.68)	(0.74)	(2.42)	(-0.47)	(-16.11)
Training	0.010***	0.021***	0.012***	-0.006	0.025***	0.010***	-0.003	0.027***
	(9.93)	(19.47)	(5.06)	(-1.44)	(3.20)	(13.55)	(-0.33)	(5.78)
Advertising & Marketing	0.006***	0.009***	0.004***	0.015***	-0.004	0.012***	- 0.038***	0.006*
	(9.59)	(11.32)	(2.93)	(2.80)	(-0.59)	(2.26)	(-3.13)	(2.56)
Software	0.006***	0.016***	0.005***	0.004	0.015***	0.003	0.006	0.017***
	(4.26)	(7.08)	(4.41)	(0.96)	(2.77)	(1.63)	(0.72)	(8.02)
Controls								
Export	0.064***	0.134	0.075***	0.208***	0.116***	0.090***	-0.118**	0.076***
	(8.95)	(5.92)	(4.41)	(8.25)	(197.88)	(3.50)	(-2.69)	(5.71)
East Germany	-0.081	-0.244	- 0.108***	-0.199***	-0.222***	-0.083	- 0.475***	- 0.122***
	(-1.64)	(-36.21)	(-11.40	(-24.00)	(-175.92)	(-1.80)	(-19.59)	(-7.26)
Group	0.010***	0.185***	0.139***	0.197***	0.170***	0.103***	0.221***	0.127***
	(5.96)	(21.11)	(10.65)	(6.69)	(149.91)	(5.53)	(14.34)	(19.84)
Observations	10229	6497	7978	817	1013	1066	379	3174

**Notes**: T-statistics in parantheses. \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Estimation results control for industryand time-specific effects. The reported values refer to LP estimation results. Manuf.=Manufacturing, ICT=Information and Communication Technology. **Data source**: Mannheim Innovation Panel (MIP).

## 6. Concluding Remarks

This paper analyses the impact of intangible capital on firm-level productivity for Germany, using data from the Mannheim Innovation Panel (MIP) over the period 2006 to 2018. Our paper presents three novel results vis-à-vis the existing literature.

First, we find a highly significant and positive relationship between intangible capital and firm-level productivity in Germany. The overall magnitude of our elasticity estimates is in line with previous estimates of an EU aggregate but our estimates suggest a higher value than those for other large EU economies, such as France and Spain, but a lower value than for Italy and the UK.

Second, we observe that both manufacturing and service industries are highly intangiblecapital intensive, and a considerable heterogeneity exists for the composition of intangible capital investments across different industries. We find that intangible capital impacts firmlevel productivity more strongly in business services – especially through investments in training and software. We conclude that intangible capital, in particular economic competencies, plays a more pivotal role in services. Therefore, to concentrate solely on manufacturing in terms of sectors and also on innovative property and software in terms of intangibles would not fully capture the importance of intangible capital on a firm's productivity.

Third, our results show that intangible capital investments by German firms have been equal to those in tangible capital since the early 2000s. Our firm-level evidence points to a greater aggregate intangible and total investment rate for Germany than suggested by international macro databases. We argue that such a striking difference between these two datasets is suggestive of a mismeasurement of intangible capital, and that incorporating microevidence into the existing macro-level studies could ameliorate the validity of data related to intangibles.

Overall, the evidence presented in our paper indicates that Germany – in line with other highly advanced economies – has been undergoing a structural change towards becoming a knowledge economy in which intangibles have become an important driver for firm-level productivity. Such a structural transformation towards becoming a knowledge economy entails policy implications for Germany's future industrial policy. We have identified three in particular.

First, in line with existing literature (see e.g. Roth 2020 and Haskel and Westlake 2018), Germany's manufacturing and service sectors would benefit from an enhanced institutional capacity that can support the ongoing structural change towards becoming a knowledge economy. This includes, amongst others, investments in public intangibles that aim at ameliorating the quality of the higher education sector and the creation of an adequate infrastructure to secure Intellectual Property Rights.

Secondly, the importance of economic competencies (such as training) for the productivity performance of German firms in manufacturing and a majority of service industries makes the incorporation of these types of intangibles into the asset boundary of the national accounts a pressing policy issue. This should be considered along with general

productivity measurement problems and the relatively low productivity of Germany with respect to the US in the market services sector.

Thirdly, the significant role of different types of intangibles for firm-level productivity challenges the current approach of innovation policy to providing vastly different investment incentives for different intangibles. While there is ample government support for firms' investment in R&D (both through grants and tax incentives), there are substantially less incentives for training, software and database activities or advertising & marketing activities. A more consistent policy approach could contribute to fully realize the productivity potential of firms by simultaneously stimulating investment in hardware, software, and various other intangibles (see Brynjolfsson 2002, 2019).

Finally, another approach for encouraging higher investment in intangibles would be to create efficient markets for trading intangibles, or the results of investments in intangibles. While markets for software and databases are well-developed, this is less true for markets for R&D (see Arora et al. 2002, Conti et al. 2013, and Monk 2009) or other intellectual property (see Agrawal et al. 2015 and Gans and Stern 2010). Markets for advertising & marketing are limited to trading brands, whereas the value of training one's own staff is particularly difficult to re-capture by firms in case people move to another job. Designing markets for intangibles that allow firms to obtain the value created by having invested in intangibles would most likely provide further incentives for this type of capital investment.

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# References

Ackerberg, D.A., K. Caves, and G. Frazer (2015), 'Identification properties of recent production function estimators', *Econometrica*, 83(6), 2411–2451.

Arora, A.A. Fosfuri and A. Gambardella (2002), *Markets for Technology: The Economics of Innovation and Corporate Strategy*. MIT Press: Cambridge, MA.

Battisti, M., F. Belloc, and M. Del Gatto (2015), 'Unbundling technology adoption and tfp at the firm level: do intangibles matter?', *Journal of Economics & Management Strategy*, 24(2), 390-414.

Bloom, N. and J. van Reenen (2002), 'Patents, real options, and firm performance?', *The Economic Journal* 112 (March), C97-C116.

Bloom, N., R. Sadun, and J. van Reenen (2012), 'The organization of firms across countries', *Quarterly Journal of Economics*, 127(4), 1663-1705.

Brynjolfsson, E. and L.M. Hitt (2000), 'Beyond computation: information technology, organizational transformation and business performance', *Journal of Economic Perspectives*, 14(4), 23-48.

Brynjolfsson, E., L.M. Hitt, and S. Yang (2002), 'Intangible assets: computers and organizational capital', *Brookings Papers on Economic Activity*, 1, 137–198.

Brynjolfsson, E., D. Rock, and C. Syverson (2019), 'Artificial intelligence and the modern productivity paradox: a clash of expectations and statistics', in A. Agrawal, J. Gans, and A. Goldfarb (eds), *The Economics of Artificial Intelligence*. University of Chicago Press: Chicago, IL, pp. 23-60.

Canibano, L., M. Garcia-Ayuso, and P. Sanchez (2000), 'Accounting for intangibles: a literature review', *Journal of Accounting Literature*, 19, 102-130.

Chappell, N. and A. Jaffe (2018), 'Intangible investment and firm performance', *Review of Industrial Organization* 52 (4), 509–559.

Conti, R., A. Gambardella, and E. Novelli (2013), 'Research on Markets for Inventions and Implications for R&D Allocation Strategies', *Academy of Management Annals* 7(1): 715-772.

Corrado, C., C. Hulten, and D. Sichel (2005), 'Measuring capital and technology: an expanded framework', in C. Corrado, J. Haltiwanger and D. Sichel (eds), *Measuring Capital in the New Economy*. University of Chicago Press: Chicago, IL, pp. 11-46.

Corrado, C., C. Hulten, and D. Sichel (2009), 'Intangible capital and U.S. economic growth', *Review of Income and Wealth*, 55(3), 661-685.

Crass, D. and B. Peters (2014), 'Intangible assets and firm-level productivity', ZEW Discussion Paper No: 14-120, Leibniz Centre for European Economic Research.

Duarte, M. and D. Restuccia (2020), 'Relative prices and sectoral productivity', *Journal of the European Economic Association*, 18(3), 1400-1443.

Duernecker, G., B. Herrendorf, and A. Valentinyi (2019), 'Structural change within the service sector and the future of Baumol disease', Unpublished manuscript.

Edquist, H. (2011), 'Can investment in intangibles explain the Swedish productivity boom in the 1990s?', *Review of Income and Wealth*, 57(4), 658-682.

Gabaix, X. (2011), 'The granular origins of aggregate fluctuations', *Econometrica*, 79(3), 733-772.

Galindo-Rueda, F. and F. Verger (2016), OECD Taxonomy of Economic Activities Based on R&D Intensity, OECD Science, Technology and Industry Working Papers, No. 2016/04, OECD Publishing, Paris.

Gans, J.S. and S. Stern (2010), 'Is there a market for ideas?', *Econometrica*, 19(3), 805–837.

GLOBALINTO (2019), New intangibles for European growth. http://www.globalinto.eu

Goodridge, P., J.E. Haskel, and G. Wallis (2017), 'Spillovers from R&D and other intangible investment: evidence from UK industries', *Review of Income and Wealth*, 63(1), 22-48.

Griliches, Z. (1979), 'Issues in assessing the contribution of research and development to productivity growth', *Bell Journal of Economics* 10(1), 92-116.

Griliches, Z. (1984) (ed.), R&D, Patents and Productivity. University of Chicago Press: Chicago, IL.

Griliches, Z. and J. Mairesse (1984), 'Productivity and R&D at the firm level', in Z. Griliches (ed.), *R&D*, *Patents, and Productivity*. University of Chicago Press: Chicago, IL, pp. 271-297.

Haskel, J. and S. Westlake (2018), *Capitalism without Capital*. Princeton University Press: Princeton, NJ.

Holmes, T.J., E.R. McGrattan, and E.C. Prescott (2015), 'Quid pro quo: technology capital transfers for market access in China', *Review of Economic Studies*, 82(3), 1154–1193.

Ilmakunnas, P. and H. Piekkola (2014), 'Intangible investment in people and productivity', *Journal of Productivity Analysis* 41(3), 443-456.

INNODRIVE Intangibles Database (2011), http://www.innodrive.org/.

Jorgenson, D.W. and Z. Griliches (1967), 'The explanation of productivity change', *Review of Economic Studies*, 34(3), 249–283.

Kaus, W., V. Slatchev, and M. Zimmermann (2020), 'Intangible capital and productivity: firmlevel evidence from German manufacturing', Unpublished manuscript.

Koh, D., R. Santaeilalia-Llopis and Y. Zheng (2020), 'Labor share decline and intellectual property products capital', *Econometrica*, 88(6), 2609-2628.

Landes, E.M. and A.M. Rosenfield (1994), 'The durability of advertising revisited,' *Journal of Industrial Economics*', 42(3), 263–276.

Lev, B. and S. Radhakrishnan (2005), 'The valuation of organization capital', in C. Corrado, J. Haltiwanger, and D. Sichel (eds), *Measuring Capital in the New Economy*. University of Chicago Press: Chicago, IL, pp. 73-110.

Levinsohn, J. and A. Petrin (2003), 'Estimating production functions using inputs to control for unobservables', *Review of Economic Studies*, 70(2), 317-342.

Marrocu, E., R. Paci, and M. Pontis (2011), 'Intangible capital and firms' productivity', *Industrial and Corporate Change*, 21(2), 377-402.

McGrattan, E.R., and E.C. Prescott (2010), 'Technology capital and the U.S. current account', *American Economic Review*, 100(4), 1493-1522.

McGrattan, E.R. and E.C. Prescott (2014), 'A reassessment of real business cycle theory', *American Economic Review*, 104(5), 177-182.

Miles, I.D., V. Belousova, and N. Chichkanov (2018), 'Knowledge intensive business services: ambiguities and continuities', *Foresight*, 20(1), 1-26.

Monk, A.H.B. (2009), 'The emerging market for intellectual property: drivers, re-strainers, and implications', *Journal of Economic Geography* 9(4): 469–491.

Nakamura, L. (2001), 'What is the U.S. gross investment in intangibles? (at least) one trillion dollars a year!', Working Paper No. 01-15. Philadelphia, PA: Federal Reserve Bank of Philadelphia Working Papers Research Department.

Nakamura, L. (2010), 'Intangible assets and national income accounting', *Review of Income and Wealth*, 56(1): S135-S155.

Niebel, T., M. O'Mahony, and M. Saam (2017), 'The contribution of intangible assets to sectoral productivity growth in the EU', *Review of Income and Wealth*, 63(1), 49-67.

Olley, S. and A. Pakes (1996), 'The dynamics of productivity in the telecommunications equipment industry', *Econometrica*, 64(6), 1263-1298.

O'Mahony, Mary and M. Vecchi (2009), 'R&D, knowledge spillovers and company productivity performance', *Research Policy*, 38(1), 35-44.

Peters, B. and C. Rammer (2014), 'Innovation panel surveys in Germany', in: F. Gault (ed.), *Handbook of Innovation Indicators and Measurement*. Edward Elgar: Cheltenham, UK, pp. 135-177.

Rammer, C. and B. Peters (2016), 'Investitionsschwäche oder Strukturverschiebung der Investitionstätigkeit? Zur Rolle immaterieller Investitionen fur die Wettbewerbsfähigkeit von Unternehmen,' Wirtschaftspolitische Blätter 1/16, 67-86.

Roth, F. and A.E. Thum (2013), 'Intangible capital and labour productivity growth', *Review of Income and Wealth*, 59(3), 486-508.

Roth, F (2020), 'Revisiting intangible capital and labour productivity growth, 2000-2015: accounting for the crisis and economic recovery in the EU', *Journal of Intellectual Capital*, 21(5), 671-690.

Stehrer, R., A. Bykova, K. Jager, O. Reiter, and M. Schwarzhappel (2019), 'Industry level growth and productivity data with special focus on intangible assets', Vienna Institute for International Economic Studies. Manuscript.

Teece, D.J. (1998), 'Capturing value from knowledge assets: the new economy, markets for know-how, and intangible assets', *California Management Review*, 40(3), 55-79.

Timmer, M., R. Inklaar, M. O'Mahony, and B. van Ark (2010), *Economic Growth in Europe:* A Comparative Industry Perspective. Cambridge University Press: Cambridge, UK.

Trunschke, M., C. Rammer, and F. Roth (2020), Measuring organisation capital at the firm level: a production function approach, ZEW Discussion Paper No. 20-021, Mannheim.

Van Ark, B., M. O'Mahony, and M.P. Timmer (2008), 'The productivity gap between Europe and the United States: trends and causes', *Journal of Economic Perspectives*, 22 (1), 25-44.

Verbic, M. and S. Polanec (2014), 'Innovativeness and intangibles in transition: the case of Slovenia', *Economic research-Ekonomska istrazivanja*, 27(1), 67-85.

# Appendix A: Additional Tables and Figures



Figure A.1: Investments in tangible and intangible capital in Germany, 2006-2017

**Notes**: The investment rates refer to the business sector, which excludes the public sector and real estate. **Source**: November 2019 release of EU KLEMS.

**Table A.2:** Percentage of firms that invest in intangibles.

Intangible Type	Investments (Percentage of Firms)
Research & Development	48.6
Design & Licenses	55.3
Training	80.6
Advertising & Marketing	79.4
Software & Databases	84.7

Notes: The results are shown by types. The ratios refer to the whole sample from 2006 to 2018.



Figure A.2: Tangible and intangible capital investment in Germany, 1992 to 2019

**Notes:** Observations in the year 2006 are normalized to 100. Figure 1 provides normalized values several types of investments recognized in the national accounts. From this figure it is clear that investment rates of intangible capital types, as exemplified by R&D and software, are developing significantly over time, surpassing all other types of tangible capital.

Data Source: DeStatis and authors' own calculations.