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DISCUSSION PAPER

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Intangible Assets and Productivity at the Firm Level: R&D versus non-R&D Intangibles

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Intangible Assets and Productivity at the Firm Level: R&D versus non-R&D Intangibles

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Abstract

Intangible assets have increasingly been identified as a main source of productivity gains. Since the pioneering work by Corrado, Hulten, and Sichel (2005), empirical research has largely focused on macro and industry-level studies, while firm-level studies have often been confined to a limited set of intangible assets, especially Research and Development (R&D). This paper employs a unique firm-level panel database that contains information on four types of intangible assets: R&D, software & databases (S&D), firm-specific human capital (HC), and brand value (BV). For R&D, we find much lower productivity returns than for S&D and HC. R&D even loses significance once controlling for other intangibles, except for high-tech manufacturing. In contrast to R&D, we find that S&D and HC tend to be the primary drivers of productivity gains, particularly in services. Our findings have implications for research policy, suggesting a stronger focus on supporting investment in non-R&D intangibles, including S&D and HC.

Keywords: Non-R&D intangibles, productivity, R&D, digitalisation, firm-specific human capital, brand value, firm-level panel data

JEL: E22, O33, O38, D24

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1. Introduction

Intangible assets are a key component of capital services and have been identified as an essential source of productivity gains and economic growth (Corrado et al. 2009, van Ark et al. 2009, Bianchi and Labory 2004). Intangible assets represent distinct types of knowledge required in the development, production, and commercialisation of goods and services. Based on the seminal work of Corrado, Hulten and Sichel (CHS 2005), it has become common to distinguish three types of intangible assets: (a) computerised information that is contained in computer software and databases; (b) innovative property, i.e., knowledge resulting from scientific research and development (R&D) and other innovative efforts; (c) economic competences, including firm-specific skills of employees, brand names, reputation, and organisational capital of the firm.

Empirical studies on the role of different types of intangible assets vis-à-vis tangible capital have been largely confined to industry- and macro-level analyses (see Roth 2025 for a recent review). These studies revealed a substantial positive impact of intangibles on both productivity and growth. While R&D is crucial for labour productivity growth in the manufacturing sector, non-R&D intangibles, including software, training, and organisational capital, are the primary drivers of labour productivity growth in service sectors (Roth 2024, Roth and Mitra 2025). Firm-level studies typically examine a single intangible asset and rarely consider the interplay of different types of intangibles and their relative importance over time, reflecting the scarcity of firm-level panel data on intangible assets. Early studies focused on R&D (see Griliches and Mairesse 1984, Griliches 1985, Mairesse and Sassenou 1991), which were later complemented by studies on computerised information (Brynjolfsson and Hitt 2003), firm-specific human capital investment (Black and Lynch 1996) and brand value (Patel 2024, Crass et al. 2019a). Only a few studies consider several intangibles and their impact on firm performance at the same time, usually covering a relatively short period of time, using ad-hoc proxies for intangible assets, or look at a specific group of firms in terms of industries or size (Marrocu et al. 2012, Crass and Peters 2014, Roth et al. 2023, He et al. 2020). Hence, more detailed and comprehensive analyses of the link between intangible assets and firm performance are highly important to better understand the mechanisms by which intangible assets contribute to economic output and how policy can support investment in intangibles that stimulate productivity growth.

A first important issue to consider is the likely interplay of different types of intangible assets, which may alter the results found in studies that consider only one type of intangible. In cases of complementarities or substitution effects among intangibles, considering different

intangibles simultaneously is likely to yield different results compared to examining a single intangible asset in isolation. Secondly, different types of intangibles are likely to exert different effects by industry, reflecting the varying relevance of different types of intangibles for competitiveness and productivity in different industries. Thirdly, the productivity impacts of intangibles may change over time, as the knowledge and technologies associated with each intangible asset change. This is particularly true for software and databases, since new digital technologies (such as artificial intelligence, big data analysis, or digital platforms) offer new potential for productivity gains.

This paper aims to close the research gap in terms of productivity impacts of different types of intangible assets at the firm level in four ways. First, in contrast to a large array of the existing literature (De Ridder 2024, Le Mouel and Schiersch 2024, Friesenbichler et al. 2025, Kaus et al. 2024, Bessen and Wang 2024), we consider four types of intangible assets: research and development (R&D), software and databases (S&D), firm-specific human capital (HC), and brand value (BV). Secondly, we use capital stock data on intangibles, providing more accurate measures than has been previously used in the existing studies that used investment data (see Bessen and Wang 2024, Roth et al. 2023). Thirdly, we investigate likely changes in productivity effects of intangibles over time. Finally, we analyse productivity effects for different industry groupings from both manufacturing and services, allowing a comparison of the relative importance of intangibles in different industries over time. Following recent literature on the heterogeneity of productivity effects caused by a right-skewed distribution of intangibles (De Ridder 2024, Le Mouel and Schiersch 2024, Kaus et al. 2024, Bessen and Wang 2024), we investigate such heterogeneity for firms with very large R&D and S&D capital stocks, respectively.

Based on micro-level productivity estimates using the Levinsohn and Petrin (2003) approach, we find lower productivity returns from R&D than from S&D and HC across industries. Once controlling for non-national accounts variables HC and BV, R&D even loses its significance. S&D and HC tend to be the main drivers of productivity, in particular in services. We find that the impact of training on firm-level productivity in high-tech manufacturing has increased over time. The same holds for software & databases in firms with a high S&D capital stock. Whereas R&D's positive impact on firm-level productivity is primarily among high-tech manufacturing firms with high R&D capital stocks, we find that even if the S&D capital stock-intensive industry yields higher productivity benefits, we find an overall positive impact of S&D on firm-level productivity throughout the economy. HC seems to be of particular importance for the firms that have lower R&D and S&D capital stocks.

The paper makes two important contributions to our understanding of the role of R&D and non-R&D intangibles for productivity, and how (research) policy can contribute to productivity gains. First, the limited productivity impact of R&D that we find for firm-level productivity challenges the findings of many firm-level studies on the productivity impact of R&D, which usually do not consider the role of non-R&D intangibles. This omission may have resulted in an overestimation of the contribution of R&D to productivity. In addition, the nature of technological change in the past decade may have shifted the sources of productivity gains from new technological knowledge in general to digital knowledge, derogating the importance of R&D for productivity. Our findings may call for some reconsideration of government policies. Particularly in service industries, supporting investment in S&D and HC promises much higher firm-level returns than supporting R&D. Even in those service industries with small S&D capital stocks, S&D investments yield higher benefits for firm-level productivity than R&D investments.

The results of our paper also point to a significant difference between firm-level results and meso- and macro-level results with respect to the productivity effects of R&D. While this study finds rather limited firm-level effects, here in particular among the R&D-capital stock intensive High-tech Manufacturing firms, meso- and macro-level studies reveal substantial positive contributions of R&D to productivity and economic growth (Adarov et al. 2022, Castelli et al. 2022), and here in particular in the manufacturing (Roth 2024) and High-tech manufacturing sectors (Roth and Mitra 2025). This difference may be explained by high R&D spillovers, likely due to less effective appropriation mechanisms available to firms in low-tech manufacturing and services. In order to secure sufficient R&D investment in these sectors, both incentives for R&D investment and more effective instruments for securing private returns from R&D are required.

The remainder of the paper is organised as follows: Section 2 offers the theory and empirical evidence. Section 3 provides an overview of the model specification, the estimation approach used, and the Data utilised. Section 4 displays the descriptive statistics. Section 5 offers our econometric results. Section 6 discusses the implications of our results for Research Policy. Section 7 concludes.

2. Theory and Empirical Evidence

2.1 Heterogeneity of Productivity Impacts of Intangibles across Industries

Developing, producing and commercialising goods and services requires a variety of inputs. In addition to fixed capital, labour and intermediary products, different types of knowledge and intangible assets are essential. Their specific role for output and productivity at the macro level has been stressed by endogenous growth theory (Romer 1986, Lucas 1988, Grossman and Helpman 1991). In empirical works, knowledge and intangible assets were often measured by R&D, i.e. the stock of technological knowledge that resulted from R&D activities in firms, universities and research organisations (see Griliches 1998). Over time, other intangible assets have been considered as well, including knowledge resulting from non-R&D innovative activities, including computer programming, training, advertising and branding, and organisational development. CHS (2005) offered a conceptual framework for these different types of intangibles that has been guiding empirical research since then. They distinguished three categories of knowledge investment: i) software, databases and other computerised information, ii) innovative property, including scientific R&D, and iii) economic competencies, including training, organisational restructuring, and marketing and branding.

There is ample evidence both from theory and empirics that knowledge contained in intangible assets is essential for performing production activities (including the development, distribution and commercialisation of goods and services) in a more efficient way and to achieve a higher quality of output (Nelson and Winter 1977). Both efficiency and quality gains from intangible assets will result in a higher productivity of the activity (Castelli et al. 2024, Marrocu et al. 2012). However, different types of knowledge are required for different types of production activities, depending on the technological nature of the production process, product characteristics, demand preferences, and market structure. Consequently, productivity impacts of a specific type of knowledge (i.e., intangible asset) are likely to vary across industries. This heterogeneity of intangibles is critical to consider when analysing the link between intangibles and productivity.

For example, in industries where the technical performance of a product largely determines the product's competitiveness (e.g., precision and speed of a machine performing a specific task, bio-chemical effect of a drug), technological knowledge about how to achieve a superior technical performance will be an essential source for productivity gains. R&D is therefore a major source of productivity-enhancing knowledge (Griliches 1998). In contrast, in

industries where flexible and rapid adaptation of products to specific user requirements is critical, computerised information and organisational capital that allows for rapid adjustment of processes are likely to be key (Brynjolfsson and Hitt 2003, Trunschke et al. 2020). In industries where products of competitors are homogenous, and quality differences are difficult to observe by users, branding and product design are likely to provide a competitive advantage that can be transferred into higher output-to-input level (Crass et al. 2019a, He et al. 2020).

This heterogeneous nature of intangibles has several implications: First, firms have to invest in different types of intangibles, depending on their production and market environment. Secondly, the productivity impact of a specific type of intangible will differ across industries, reflecting different production and market environments. Thirdly, when the role of intangibles for competitiveness in a specific industry changes, changes in the productivity impacts of different intangibles are likely to occur. Such changes may be related to new upcoming technologies, such as digital technologies, or to changes in market structures, such as the entrance of new competitors with different competitive advantages (e.g., from emerging economies) or changes in user preferences.

For analysing productivity impacts of intangibles, this situation implies that one should consider as many relevant intangibles as possible and analyse productivity impacts of intangibles for different sectors separately. For analysis at the total economy level, i.e., cross-sector analysis, it is likely that high productivity impacts of a particular intangible asset within a specific sector will disappear at the aggregated level due to insignificant productivity contributions of this intangible asset in other sectors.

2.2 Empirical Firm-level Evidence on Intangibles and Productivity

Following in the footsteps of Brynjolfsson et al (1993) and Nakamura (2001), the seminal contribution by Corrado et al. (2005) sparked a series of empirical analyses on the relationship between intangible capital and labour productivity growth. In the beginning, these analyses have analysed *aggregate* intangible capital on productivity growth. Such macro-country-based studies found a positive contribution of intangibles to growth in the US (Corrado et al. 2009), the UK (Marrano et al. 2009), Sweden (Edquist 2011), and Japan (Fukao et al. 2009). Using freshly constructed macro-datasets within the FP7 projects COINVEST (Van Ark et al. 2009) and INNODRIVE (Roth and Thum 2013, Roth 2022) and Intan-Invest projects (Corrado et al. 2013) these results were confirmed for a cross-country analysis for an EU10 country sample (Van Ark et al. 2009), EU-13 country sample (Roth and Thum 2013) as well as an EU 15 and

US country sample (Corrado et al. 2013). Results at the country level, which differentiated between the three broad dimensions, found non-R&D economic competencies (Roth and Thum 2013, Roth 2020, c.f. Adarov et al. 2022) to be the major driver for labour productivity growth. More specifically, studies that further differentiated between six individual intangibles found firm-specific human capital to be a major driver for labour productivity growth (Roth 2024). Analysing a GVC model specification, Adarov et al. (2022) found that software to impact labour productivity growth positively.

The early literature at the meso level clarified the importance of R&D on growth (Griliches 1980, Gross and Helpmann 199). Latest empirical evidence points to a positive relationship between R&D and labour productivity growth. At the meso level cross-country-sectoral studies used the newly constructed INDICSER (Niebel et al 2017) and Intan-Invet dataset (Corrado et al. 2016), which differentiated between the goods-producing and services sectors (Corrado et al 2016, Niebel et al 2017) and differentiated between R&D and Non-R&D intangibles (Corrado et al. 2016). Further empirical results split sectoral aggregate intangibles into R&D, software, and economic competencies and found a positive impact of R&D and software in the manufacturing sector but no impact of software in the service industry (Adarov et al. 2022). In this literature, economic competencies are significantly negative or insignificantly related to labour productivity growth. In contrast, Piekkola (2018) finds all three indicators R&D, ICT and organisational capital to be important drivers for labour productivity growth for the market economy. However, he does not differentiate between services and goods-producing sectors, nor between broad sub-sectors. The latest empirical results differentiated between six individual intangibles and five sub-sectors (Roth 2024). The analysis finds that while R&D is important for manufacturing, firm-specific human capital and organisational capital are important for the services sector, and here in particular for distributive and other sectors. A most recent work once more differentiates between four intangibles and two broad sectors (Roth and Mitra 2025) and finds non-R&D intangibles, including ICT-tangibles, software, organisational capital and firm-specific human capital to be important for the services sector, while non-ICT tangible capital to be necessary for the goods-producing sector and R&D for manufacturing and here in particular for the high-tech manufacturing sector. Such results are more nuanced than analyses that find R&D to have a positive impact on the whole market economy (Adarov et al. 2022, Castelli et al. 2022). These last studies clarify that a differentiated policy strategy is more likely to be needed depending on the individual sector.

The finding that R&D is no longer significant in the aggregate market economy has also been theoretically modelled and empirically confirmed at the micro level by a study by De Ridder (2024). Analysing the US and French cases, De Ridder (2024) finds that the two national accounts variables R&D and S&D investments are intensely concentrated in the hands of a few leading firms, which make a substantial profit through higher markups. Given the high fixed costs for R&D and S&D investments, market entry becomes less probable. After initially boosting productivity, an increase in intangibles causes a decline in productivity. Similar results are found by Brynjolfsson et al. (2021), which make the argument for software and AI investment to meet the J-curve empirical effect. This leads to a situation in which increased software and R&D investments actually result in a decline in macro-level productivity growth. Similar results are found in Germany by Le Mouel and Schiersch (2024). The authors find that firms with high aggregate intangible capital stock endowment are found to have higher productivity than those with lower intangible capital stocks. Such results are in line with Kaus et al (2024), who find that R&D and S&D are essential for the whole market economy but also driven by the firms with the largest intangible capital endowment. They find that over time, investment in intangibles in manufacturing increases and surpasses tangible investments, but intangible investment is concentrated in a few firms. Their findings suggest that investments in R&D and software are an important production factor for firms in manufacturing.

The significance of R&D for productivity is also examined through a complex of analyses grouped around the INNODRIVE and GLOBALINTO micro-approach. These micro-level studies highlight the importance of R&D on firm-level productivity using Linked Employee Data (Ilmakunnas and Piekkola 2014, Verbic and Polanek 2014, Piekkola 2016). Using such data sources, most of these studies, however, only analyse a non-complete set of intangibles, focusing on three distinct intangibles ICT, R&D, and organisational capital (Piekkola et al. 2025), which measure the effective use and quality of intangibles.

All of the above-mentioned papers either analyse intangible capital as an aggregate (Le Mouel and Schiersch 2024) or analyse a limited amount of intangible capital indicators, or focus solely on the two national accounts, intangible R&D and S&D (De Ridder 2024, Friesenbichler et al 2025, Kaus et al. 2024) or a limited set of non-national accounts intangibles (Piekkola et al. 2025). However, as highlighted by Brynjolfsson et al (2021) and Corrado et al (2005), intangible capital should best be understood as a broader concept of innovation, including the two national accounts intangibles R&D and software, next to the complementary non-national account intangible firm-specific human capital, organisational capital and brand value.

Microeconomics findings, which include a broader set of intangibles, are those of the seminal study by Marrocu et al. (2012). The authors construct an intangible capital indicator from a range of different intangible indicators. However, the authors only analyse the aggregate concept, not the individual intangibles. Other papers that analyse a broader set of intangibles on productivity include Batisti et al. (2015) and Bontempi and Mairesse (2015). These studies, however, are not based on the theoretical framework of Brynjolfsson (2021) or Corrado et al. (2005) and do not include firm-specific human capital and brand value. Most importantly, none of the papers mentioned above analyses the sub-sectors of the market economy. However, considering sub-sectors is essential to understand the heterogenous impact of the individual intangibles for formulating adequate policy implications (Kumbhakar et al. 2012, Ortega-Argilés et al. 2015, Roth et al. 2023). Analysing a comprehensive set of intangible capital indicators for a wide array of sub-sectors at the sectoral level, the findings by Roth (2024) and Roth and Mitra (2025) indicate that while R&D is crucial for labour productivity growth in the manufacturing sector, non-R&D intangibles, including software, firm-specific human capital, and organisational capital, are the main drivers of labour productivity growth in services.

At the firm-level, Roth et al. (2023) analyse the impact of intangibles on firm-level productivity, using panel data from Germany's contribution to the Community Innovation Survey (CIS), covering 2006 to 2018. The authors find a highly significant and positive relationship between intangible capital and firm-level productivity in Germany, with elasticity estimates in line with those from previous EU aggregate estimates. Like the meso study by Roth (2024), these authors find that non-R&D intangibles at the sectoral level, such as software and databases, firm-specific human capital, and brand value, predominantly contribute to the positive effect of intangibles on firm-level productivity. Although non-R&D intangibles are important to both the goods and services sectors, they affect firm-level productivity more strongly in the services sector. Furthermore, they find that R&D does not have an equally strong effect on firm-level productivity compared to economic competencies, software, and databases.

In accordance with the theoretical assumptions and empirical findings by De Ridder (2024), Kumbhakar et al. (2012), Ortega-Argilés et al. (2015), Roth et al. (2023), and Roth and Mitra (2025), only find a strong productivity effect of R&D in high-tech manufacturing or R&D frontier firms. Such findings are in line with a study from Portugal, which stresses the importance of firm-specific human capital over R&D and S&D for explaining firm-level productivity across a large sample of Portuguese firms (Goncalves and Carreira 2023).

Our paper builds on existing firm-level studies of intangibles and productivity by covering both tangible and intangible assets and employing standard econometric techniques to analyse the productivity impacts of intangibles (the Levinsohn-Petrin and Olley-Pakes approaches). Our paper aligns the different findings in the existing literature. By using a purely national accounts model specification, it confirms the findings by the existing literature (Kaus et al. 2024, Friesenbichler et al. 2025), namely that R&D and S&D have a positive impact on firm-level productivity. On the other hand, the paper shows that once including the additional non-national accounts intangibles, HC, and BV, R&D loses significance. This aligns with Roth et al. (2023) but complements all existing studies in this field. Moreover, this paper, by splitting its sample into firms with large R&D and S&D capital stocks vis-à-vis firms with small R&D and S&D capital stocks, finds that while R&D is only beneficial for the R&D capital stock intensive High-tech Manufacturing sector, S&D investments, next to having a higher impact in S&D capital stock intensive firms, also benefit firms throughout almost all analysed sub-sectors.

In more detail, we implement four important extensions vis a vis the existing literature First, in contrast to Roth et al. (2023) we estimate a stepwise equation, first the two national accounts and secondly cover four types of intangible assets (R&D, software & databases, firm-specific human capital, brand value) which enables a more accurate identification of the productivity impacts of each intangible assets by avoiding likely distortions in estimated coefficients due to the omission of relevant other intangibles. Secondly, we use capital stocks instead of investment data, which is another feature for producing more accurate estimates. Thirdly, within our large set of industries, including several service and manufacturing industries, we differentiate between firms with high R&D and S&D capital stocks vis-à-vis firms with lower capital stocks. Finally, we cover a longer time period, allowing us to run separate estimations for sub-periods and providing evidence on likely changes in the link between intangible assets and productivity over time.

3. Model, Estimation Approach and Data

3.1 Empirical Model

Following the approach by Roth et al. (2023), the following production function at the firm level is used as starting point:

$$\boldsymbol{Y_{i,t} = A_{i,t} M_{i,t}^{\theta} K_{i,t}^{\alpha} L_{i,t}^{\beta} R_{i,t}^{\gamma}} \qquad \text{(Eq. 1)}$$

where $\boldsymbol{Y_{i,t}}$ denotes gross output, $\boldsymbol{A_{i,t}}$ total factor productivity, $\boldsymbol{M_{i,t}^{\theta}}$ intermediate inputs, $\boldsymbol{K_{i,t}^{\alpha}}$ physical capital, $\boldsymbol{L_{i,t}^{\beta}}$ labour, and $\boldsymbol{R_{i,t}^{\gamma}}$ intangible capital. Apart from the inclusion of intangible capital, equation (1) represents a standard production function, with no restrictions placed on the elasticity parameters θ, α, β and γ. In the case of θ + α + β + γ = 1, the functional form reduces to the Cobb-Douglas case. For estimation purposes, equation (1) is log-normalised, which yields the following Equation (2) (where the lower-case variables indicate the log-normalised values):

$$\boldsymbol{y_{i,t} = a_{i,t} \theta m_{i,t} \alpha k_{i,t} \beta l_{i,t} \gamma r_{i,t}} \quad \text{(Eq. 2)}$$

It is also assumed that the productivity term $\boldsymbol{a_{i,t}}$ consists of a common factor $\boldsymbol{\omega}$, an unobservable productivity term $\boldsymbol{q_{i,t}}$ known by the firm, time dummies $\boldsymbol{d_t}$, which control for shock that affects all firms, a vector of control variables $\boldsymbol{x_{i,t}}$, and an error term $\boldsymbol{\varepsilon_{i,t}}$, which satisfies the standard properties:

$$\boldsymbol{a_{i,t} = \omega + q_{i,t} + d_t + \delta x_{i,t} + \varepsilon_{i,t}} \quad \text{(Eq. 3)}$$

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

$$\boldsymbol{y_{i,t} = \omega + q_{i,t} + d_t + \theta m_{i,t} + \alpha k_{i,t} + \beta l_{i,t} + \gamma r_{i,t} + \delta x_{i,t} + \varepsilon_{i,t}} \quad \text{(Eq. 4)}$$

In a first step we then split the aggregated intangible term $r_{i,t}$ into two types of intangible capital services as already incorporated into the national accounts: technological knowledge based on R&D ($\boldsymbol{rd_{i,t}}$) and software and databases ($\boldsymbol{sd_{i,t}}$). This step leads to Equation (5) and reads as follows:

$$y_{i,t} = \omega + q_{i,t} + d_t + \theta m_{i,t} + \alpha k_{i,t} + \beta l_{i,t} + \iota rd_{i,t} + \nu sd_{i,t} + \delta x_{i,t} + \varepsilon_{i,t} \quad \text{(Eq. 5)}$$

In a second step we then add two types of intangible capital services which have not yet been incorporated into the national accounts but have been identified by the CHS concept as important intangibles for driving productivity growth: firm-specific human capital ($\boldsymbol{hc_{i,t}}$) and brand value ($\boldsymbol{bv_{i,t}}$). This step leads to Equation (6) and reads as follows:

$$y_{i,t} = \omega + q_{i,t} + d_t + \theta m_{i,t} + \alpha k_{i,t} + \beta l_{i,t} + \iota rd_{i,t} + \nu sd_{i,t} + \zeta hc_{i,t} + \eta bv_{i,t} + \delta x_{i,t} + \varepsilon_{i,t} \quad \text{(Eq. 6)}$$

Note that even Eq. 6 does not include two components of intangibles that are part of the CHS concept, non-R&D innovative property and organisational capital. As for non-R&D innovative property, investment in non-R&D innovation activities is closely related to software and database activities as well as firm-specific human capital and brand value related to

innovation. These expenditures are already captured by *sd*, *hc* and *bv*. Further non-R&D innovation investment mainly refers to design activities and conceptual work. Attempts to collect data on these investments in the context of the innovation survey revealed that such investment is very low and difficult to measure accurately (see Rammer and Schubert 2022).

As for organisational capital, measurement is even more difficult (Nonnis et al. 2025), particularly when it comes to establishing monetary capital stock data for this type of intangible, since it is not primarily financial investment needed to build up organisational capital, but rather social relations between employees and management practices (see Trunschke et al. 2020). Given the measurement difficulties for both components, we do not include these types of intangibles in our analysis.

3.2 Estimation Approach

A well-known problem of estimating firm-level production functions as expressed in equations 5 and 6, is endogeneity. It results from the firms' decision about inputs to the production based on knowledge about possible production shock resulting from input decisions. When the firms productivity level affects the choice of inputs, it will be correlated with productivity and therefore with the error term in the equation. Due to this circumstance, OLS estimators will be biased and inconsistent (Marschak and Andrews 1944). To resolve this issue, most economic studies use the methods developed by Olley and Pakes (1996) (OP) and Levinsohn and Petrin (2003) (LP). The OP estimation approach solves endogeneity by using a non-parametric investment function. To investigate the unobserved productivity shocks, the observable investments decision is used as a proxy variable. For this case, we use the accumulated stock of tangible assets as the state variable and tangible investments as the proxy, while labour and intangible investments are free variables. Building upon the OP approach, the LP estimation uses intermediate inputs instead of capital stocks as a control for productivity shocks, which are observed by the firm. In the following analysis we focus on the LP estimation, because using intermediate inputs is the recommended control variable (Ackerberg et al. 2015, Ackerberg 2021). A Wooldridge System GMM estimation approach (Wooldridge 2009) is used for robustness checks (see Tables B5 and B6 in Appendix B).

3.3 Data

For estimating the empirical model presented above, we use firm-level panel data from the German Innovation Survey. This survey is designed as an annual panel survey and is conducted

by the Centre for European Economic Research (ZEW) on behalf of the German Federal Government. The panel survey is called Mannheim Innovation Panel (MIP) after the city in which ZEW is located. The MIP is the German contribution to the Community Innovation Survey (CIS) of the European Commission and shares all conceptual and quality features of the CIS. Differently to most other national CIS, the MIP is conducted annually and targets a panel sample of firms (based on a stratified random sample which is refreshed every second year). In addition, the MIP covers more service sectors than the standard CIS and also includes very small firms with 5 to 9 employees (see Peters and Rammer 2023 for more details on the MIP).

For model estimations, we need data on sales, intermediaries, employment, tangible capital and intangible capital. For the first four variables, the MIP directly collects the relevant data. Sales are defined as net turnover, intermediaries include all expenditure for materials, services and other inputs (e.g. energy), employment is measured in full-time equivalents as annual average, and tangible capital is measured as the gross amount of fixed assets (property, plant and equipment) at the beginning of a calendar year.

The MIP does not collect capital stock data on intangibles, but collects data on expenditure for R&D, S&D, firm-specific training, and advertising & marketing (i.e. expenditure used to build up brand value and firm reputation, excluding expenditure on sales activities and distribution). The MIP has been frequently used for productivity analysis in the past (see Griffith et al. 2006, Janz et al. 2004, Czarnitzki et al. 2023, Czarnitzki 2005, Peters et al. 2017, 2018), including analyses on the role of different types of intangibles (see Crass and Peters 2014, Roth et al. 2023, Trunschke et al. 2020). While the existing studies used expenditure data on intangibles, this paper makes an attempt to establish capital stock data for the four types of intangibles, using investment data for each intangible. Capital stock data are measured using the perpetual inventory method and a uniform 20% depreciation rate for each intangible. We first estimate a starting base for each intangible asset, employing a similar method as the one used by Friesenbichler et al. (2025), and use annual investment data to arrive at capital stock data for the years 2011 to 2022. For R&D, the MIP started to collec R&D expenditure data (for both in-house R&D and contracted-out R&D) in the year 1992. In order to avoid double-counting, R&D expenditure for tangible assets (e.g., laboratory equipment) is excluded from R&D expenditure data. For HC, investment data (expenditure on firm-specific training for employees) starts in 1994. The long investment data series for R&D and HC imply that the choice of the start year value is practically irrelevant for the capital stock data from 2011 onwards. For BV, the first year for investment data (expenditure on advertising and

marketing) is 2006. Investment data on S&D has been collected in the MIP only from 2011 on, requiring the estimation of a base stock for 2010.

The base capital stocks are estimated by using capital stock data for fixed assets (data on which are collected in the MIP) and weighting this capital stock with the firm-specific ratio of intangible investment to investment in fixed assets (see Friesenbichler et al. 2025). Note that the MIP is not a balanced panel, but many firms show gaps in data. In order to fill in gaps for investment data, missing data points were interpolated at the firm level. All monetary variables (sales, intermediaries, investment, tangible capital stock) are measured in prices of 2015, using the GDP deflator for Germany.

The number of observations in the MIP with valid data on all variables required for estimating the empirical models is 9,335 distinct firms for the time period 2011 to 2022, summing up to 66,599 firm-year observations.

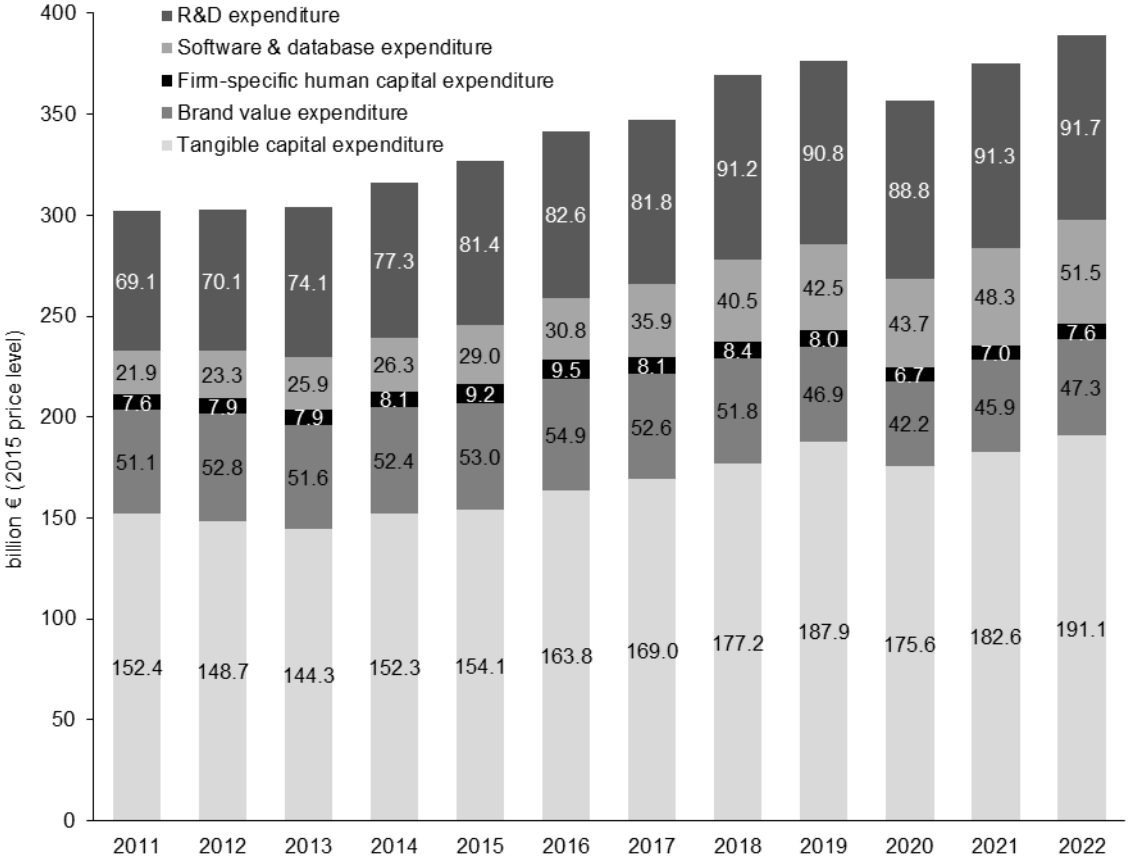
The observation period includes the years of the COVID-19 pandemic, which had strong negative effects for some parts of the German economy, while other parts experienced rather minor disruptions, and a small fraction of firms even reported positive business impacts (see Trunschke et al. 2024). In order to control for the special effects of COVID on firm productivity, we include a variable that measures the revealed impact of the pandemic on the firm's business activities during 2020 and 2022, based on a dedicated question in the MIP in the surveys conducted in the years 2021 and 2023. The question used a 6 point Likert scale, ranging from extremely negative (i.e. the business had to close down major parts of its activities) to very positive (i.e. substantial increase in sales due to additional demand, for example in the medical equipment industry).

4. Descriptive Statistics

The amount of expenditure in tangible and intangible assets among the group of firms analysed in this paper clearly increased over time in real terms (Figure 1**Fehler! Verweisquelle konnte nicht gefunden werden.**). In 2011, firms in Germany in the industries and size classes covered by the German innovation survey invested 302.2 billion Euro (at 2015 price level) in tangible assets and the four intangible assets considered in this paper: R&D, S&D, HC, BV. Up to 2022, this amount increased to 389.3 billion Euro (again at 2015 price level), corresponding to a compound real annual growth rate of 2.3%. Almost half of this investment was in tangible assets (48.7% on average from 2011 to 2022), 24.1% in R&D, 14.7% in BV, 10.2% in S&D, and 2.3%

in firm-specific human capital. The rather small amount of firm-specific human capital expenditure (about 8 billion Euro per year) is astonishing, but consistent with the result of the official vocational and continuing training survey of the Federal Statistical Office of Germany.

Figure 1. Investment in tangible and four types of intangible capital in Germany*, 2011 to 2022 (2015 price level)

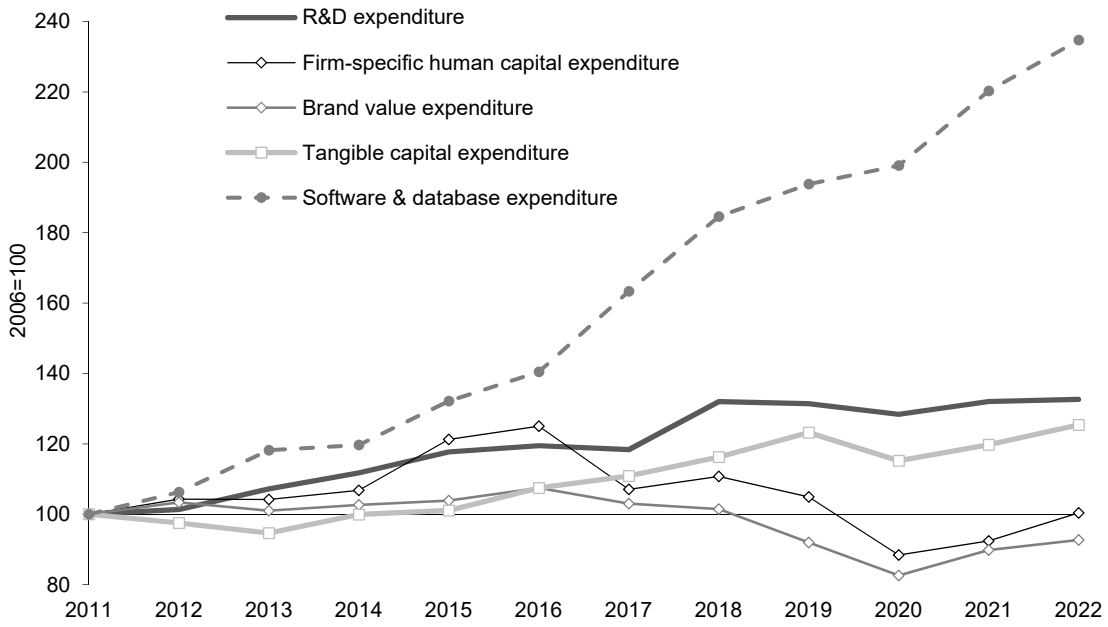


* Firms within the sector and size coverage of the MIP.
Source: Mannheim Innovation Panel (MIP); Destatis: detailed National Accounts statistics, weighted data.

Figure 2 shows the dynamics of tangible and intangible investment in Germany in the 12 years covered by this paper. The most substantial increase is reported for investment in S&D, which was 135% higher in 2022 as compared to 2011. R&D expenditure grew by 20% in real terms between 2011 and 2018, but did not show further real increases in more recent years, partly reflecting the challenging economic environment since 2019 of the German economy.

Expenditure on BV as well as firm-specific human capital expenditure was at about the same real level in 2022 as it was in 2011.

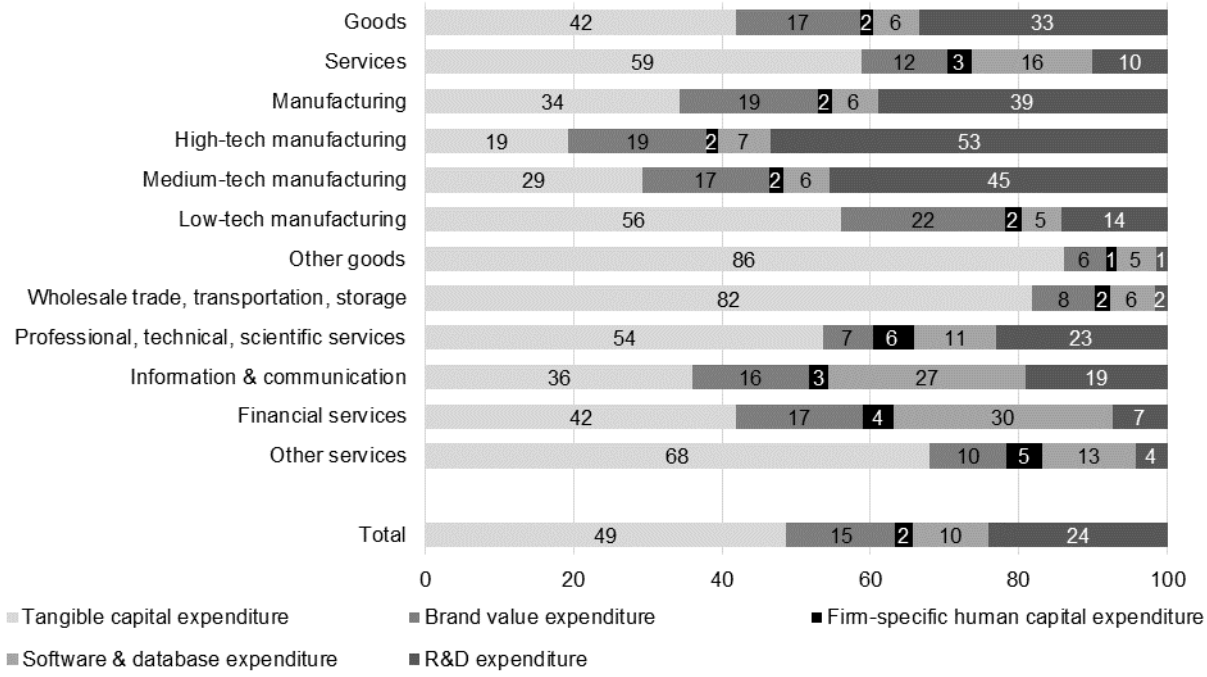
Figure 2. Dynamics of tangible and four types of intangible investment in Germany*, 2011–2022 (2015 price level)



* Firms within the sector and size coverage of the MIP.
Source: Mannheim Innovation Panel (MIP); Destatis: detailed National Accounts statistics, weighted data.

A key focus of this paper is on sector differences in intangible assets and their impact on productivity. Descriptive results reveal that the composition of tangible and intangible investment greatly differs across sectors. The goods-producing sector (manufacturing, mining, utilities, recycling) shows a much higher share of R&D expenditure as compared to the service sector, whereas S&D expenditure have a much higher weight in total investment in the service sector (see Figure 3). Within the goods-producing sector, high-tech manufacturing reports the highest share for R&D investment (53% for the 2011-2022 period), while low-tech manufacturing mainly invests in tangible assets (56%). The share of tangible investment is highest in the other goods-producing sector (mining, utilities, recycling) with 86% and in wholesale trade, transportation, and storage (82%). The service sectors' information and communication (including IT services), and financial services report the highest share of investment in software & databases (27% and 30%, respectively). The highest share of R&D expenditure within the service sectors is for professional, technical and scientific services (which include engineering and R&D services).

Figure 3. Share of tangible and four types of intangible investment by sector in Germany* (average 2011–2022)



* Firms within the sector and size coverage of the MIP.
Source: Mannheim Innovation Panel (MIP); Destatis: detailed National Accounts statistics, weighted data.

Table 1 shows the summary statistics of our model variables.[1] The mean value of output (sales) among the 66,599 firm-year observations is 89 million Euro. Intermediary inputs amount to 55 million Euro on average. The average number of employees (in full-time equivalents) is 271. The average stock of tangible assets is 53.7 million Euro and is almost twice the size of the average stock of intangible assets, which sums up to 27.2 million Euro, of which 14.3 million relate to R&D, 8.7 million to brand value, 3.2 million to software & databases, and 1.0 million to firm-specific human capital. While the amount of annual investment in tangible and intangible assets is about the same (see Figure 1), the higher amount for tangible stock assets reflects the lower depreciation rate for this type of assets. The COVID indicator ranges from -3 (extremely negatively affected) to 2 (strongly positively affected). The mean value of -0.11 indicates that the majority of firms in our sample was negatively affected by the pandemic. The small negative value results from the fact that for the non-COVID years 2011 to 2019, all firms have a value of zero for this indicator.

[1] The summary statistics for all the individual sub-sectors and the differentiation with regards to the Top 20% and Lower 80% capital stocks can be found in the additional Tables A1-A5 in Appendix A.

Table 1. Summary statistics of model variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million €)	66,599	89.312	965.189	0.0143	77,069
Intermediary input (million €)	66,599	55.285	668.206	0.000513	64,405
Labour (head count)	66,599	271.026	2,540.521	1	183,991
Tangible capital stock (million €)	66,599	53.718	810.813	0.000153	58,855
Investment in research & development (million €)	66,599	14.271	308.074	0	29,882
Investment in firm-specific human capital (million €)	66,599	0.971	12.916	0	973
Investment in brand value (million Euro)	66,599	8.713	217.769	0	22,269
Investment in software & databases (million €)	66,599	3.175	91.153	0	10,355
Covid	65,582	-0.115	0.518	-3	2

Monetary variables are measured in million Euro (m€) at the 2015 price level.
Source: Mannheim Innovation Panel (MIP).

5. Econometric Results

5.1 National Accounts Intangibles

In a first step, we consider only those two intangibles that are considered in national accounts: R&D and S&D. Table 1 reports the results for the estimation of equation 5 based on the Levinsohn-Petrin estimator for the entire 12-year period (2011-2022) as well as for three sub-periods: 2011-2015, 2016-2019, and 2020-2022. The results for the 2020-2022 sub-period are reported for a model variant excluding the indicator on COVID affectedness and a variant including this indicator. The results are shown for the entire market economy (columns 1 to 5), services (columns 6 to 10), and goods production (manufacturing, mining, and utilities; columns 11 to 15).

When analysing the market economy over the entire time period based on 66,599 firm-level observations (see column 1), we find highly significant coefficients for R&D and S&D. While the impact of S&D on firm-level productivity is sizable (0.0243), the one for R&D is much lower (0.00392).[2]

When differentiating between services and goods-producing sectors and the three time periods, we find that the impact of S&D on firm-level productivity is primarily driven by services and the 2016-2019 period. The productivity impact of S&D in services (0.0386) is three times larger than the impact in the goods-producing sector (0.0126). This finding holds for the entire time period and for the three sub-periods. The inclusion of the COVID-

[2] Moreover, as can be witnessed in Table B1 in the Appendix when controlling for S&D, the R&D impact on firm-level productivity is already almost halved from 0.00608 when only analysing R&D in Table B1 to 0.00392 when controlling for S&D.

affectedness indicator (columns 5, 10, and 15) slightly dampens the impact of S&D on firm-level productivity.

The result for R&D is as expected, since we find a significant positive coefficient in the estimations for the entire economy, and when splitting the sample by the two main sectors. This result is thus in line with most findings in the literature, which usually report a positive productivity impact of R&D (Kaus et al 2024, Friesenbichler et al. 2025). However, the results for our R&D are still somewhat surprising. First, unexpectedly, the magnitude of the impact of R&D is only a small share compared to that of S&D – practically one-sixth of the S&D impact. Second, it is peculiar that the magnitude for the market economy is driven by services rather than by the goods-producing industry.

We thus wonder whether these unexpected R&D results relate to industry heterogeneity. While the results for the entire sample are driven by firms in industries where their own R&D seems to be of little relevance to productivity, there are some industries where R&D is a highly significant driver of productivity. To analyse industry heterogeneity, Table 3 separates the goods-producing sector into high-tech, medium-tech, and low-tech manufacturing (following an OECD classification, see Galindo-Rueda and Verger 2016) and other goods (mining & utilities), and the service sector into trade, transportation & storage, information & communication, professional services, and other services. The results for individual industries differ substantially. We find a highly significant impact of R&D on productivity in the manufacturing sector (0.0049), which is driven by high-tech manufacturing (0.00605). High-tech manufacturing mainly includes pharmaceuticals, electronics, machinery, vehicles, and chemicals. In the other sub-sectors of the goods-producing sectors, R&D remains insignificant. In services, significant positive impacts of R&D on productivity are found in transportation & storage, as well as other services.

Interestingly, the impact of R&D on productivity in these two service sub-sectors is up to threefold (0.0167 and 0.0199) compared to high-tech manufacturing. The estimations for individual industries also reveal interesting results for other types of intangibles. S&D is a highly significant driver of productivity in each industry, except for other goods. When analysing sub-periods for individual industries over time (see Tables B3 and B4 in Appendix B), we find that the impact of R&D on firm-level productivity has increased over time in all industries of the goods-producing sector. In services, increasing importance over time is found for S&D in professional services.

Table 2. Intangible Capital and Firm-Level Productivity – LP Estimations for Market Economy, Services and Goods Sectors

	(1) ME 2011-2022	(2) ME 2011-2015	(3) ME 2016-2019	(4) ME 2020-2022	(5) ME 2020-2022	(6) Services 2011-2022	(7) Services 2011-2015	(8) Services 2016-2019	(9) Services 2020-2022	(10) Services 2020-2022	(11) Goods 2011-2022	(12) Goods 2011-2015	(13) Goods 2016-2019	(14) Goods 2020-2022	(15) Goods 2020-2022
Labour	0.504***	0.504***	0.501***	0.505***	0.513***	0.565***	0.573***	0.557***	0.566***	0.572***	0.410***	0.411***	0.411***	0.407***	0.417***
	(50.00)	(57.86)	(40.25)	(40.92)	(38.63)	(37.44)	(33.60)	(29.94)	(26.93)	(23.05)	(39.89)	(29.88)	(31.10)	(26.10)	(24.77)
Materials	0.423***	0.392***	0.415***	0.345***	0.329***	0.318***	0.344***	0.213***	0.228***	0.212***	0.504***	0.490***	0.506***	0.510***	0.343***
	(203.59)	(16.49)	(39.18)	(5.85)	(5.58)	(11.39)	(23.99)	(6.37)	(3.93)	(5.24)	(31.29)	(25.58)	(8.98)	(16.09)	(5.85)
Tangible Capital	0.0773***	0.0467***	0.0720***	-0.0161	0.0773***	0.0591***	0.0747***	0.0721***	0.00951	0.109***	0.0549***	0.0429***	0.0518***	0.0631***	0.0402
	(35.59)	(5.41)	(31.84)	(-0.63)	(3.99)	(5.37)	(16.14)	(4.34)	(0.37)	(4.20)	(7.84)	(5.85)	(3.76)	(4.66)	(1.46)
Research & Development	0.00392***	0.00411***	0.00352***	0.00409***	0.00487***	0.00635***	0.00827***	0.00448*	0.00540*	0.00695**	0.00286**	0.00245*	0.00320**	0.00321*	0.00334**
	(3.92)	(3.30)	(2.64)	(3.08)	(3.03)	(3.07)	(3.16)	(1.75)	(1.75)	(2.13)	(2.55)	(1.91)	(2.35)	(1.82)	(2.21)
Software & Databases	0.0243***	0.0237***	0.0284***	0.0194***	0.0191***	0.0386***	0.0388***	0.0426***	0.0324***	0.0295***	0.0126***	0.0111***	0.0167***	0.00956***	0.0107***
	(11.93)	(10.58)	(11.77)	(6.54)	(6.05)	(10.75)	(7.55)	(8.77)	(6.25)	(4.63)	(6.29)	(4.79)	(5.87)	(3.06)	(3.54)
covid					0.0640***					0.0677***					0.0929***
					(2.66)					(3.33)					(4.61)
N	66599	28789	23062	14748	13731	26655	11253	9335	6067	5658	39944	17536	13727	8681	8073

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table 3. Intangible Capital and Firm-Level Productivity – LP Estimations for Services and Goods Sub-Sectors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Goods Total	Manufacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.410***	0.405***	0.424***	0.418***	0.395***	0.413***	0.565***	0.479***	0.453***	0.708***	0.688***	0.505***
	(40.29)	(36.15)	(23.37)	(20.42)	(17.67)	(15.17)	(41.98)	(9.43)	(11.37)	(21.13)	(29.92)	(15.06)
Materials	0.515***	0.503***	0.417***	0.503***	0.524***	0.448***	0.333***	0.430***	0.267***	0.283***	0.204***	0.346***
	(214.54)	(49.40)	(9.70)	(22.50)	(11.83)	(47.27)	(22.70)	(13.38)	(5.02)	(14.71)	(7.24)	(92.96)
Tangible Capital	0.0734***	0.0406***	0.0370***	0.0505***	0.0598***	0.0513***	0.0773***	0.0530***	0.0296	0.0222***	0.0354***	0.117***
	(30.64)	(12.10)	(2.93)	(5.74)	(6.42)	(7.66)	(18.16)	(3.72)	(1.43)	(3.41)	(3.16)	(27.09)
Research & Development	0.00286***	0.00409***	0.00605***	0.00241	0.00256	-0.00597*	0.00635***	-0.00293	0.0167***	0.00203	-0.00127	0.0199***
	(2.77)	(3.50)	(2.72)	(1.60)	(1.16)	(-1.74)	(3.06)	(-0.51)	(3.24)	(0.43)	(-0.43)	(3.30)
Software & Databases	0.0126***	0.0135***	0.0120***	0.00989***	0.0175***	0.0103*	0.0386***	0.0207**	0.0318***	0.0337***	0.0337***	0.0511***
	(5.69)	(5.55)	(3.40)	(3.21)	(4.23)	(1.88)	(12.04)	(2.18)	(3.11)	(4.25)	(4.91)	(6.11)
N	39944	32432	11853	12123	8456	7512	26655	3393	3981	4441	9000	5840

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

5.2 Extended Model Specification

So far, we analysed the impact of the two national accounts intangibles R&D and S&D on firm-level productivity. In the following, we report the results for all four intangibles (R&D, S&D, HC, BV), which cover most components of the theoretical framework of CHS (2005), as displayed in equation 6. The estimation results are shown in Table 4. For the market economy and the entire time period, we find a highly significant and sizeable impact of S&D (0.0177) and HC (0.0203) on firm-level productivity (see column 1 in Table 4). In contrast, we find a much lower coefficient for BV (0.00579). Most interestingly, the impact of R&D on firm-level productivity is reduced in a sizeable manner (0.00116) and becomes insignificant.

When differentiating between services and goods production and the three time periods, we find that the impact of S&D on firm-level productivity is primarily driven by the services and the 2016-2019 period. The productivity impact of S&D in services (0.0303) is four times larger than the impact in goods production (0.00758). This finding holds for the entire time period and for each sub-period. The inclusion of the COVID indicator (columns 5, 10 and 15) slightly dampens the impact of S&D on firm-level productivity. For the productivity impact of BV, we also find significantly higher coefficients in services compared to goods production, but no clear time trend. For HC, the productivity impact is very similar in both sectors.

The result for R&D is somewhat unexpected at first sight, since we find an insignificant coefficient of small magnitude in the estimations for the entire economy, and insignificant results when splitting the sample by the two main sectors. Thus, it seems that R&D loses its relevance once other intangibles are included.

The unexpected R&D results might be related to industry heterogeneity. Table 5 reports the estimation results differentiated by different sub-sectors of services and goods production. In contrast to the results of the existing literature (Roth et al. 2023), R&D remains insignificant even in high-tech manufacturing. We find a positive impact of R&D on firm-level productivity only in transportation & storage (0.0164) and other services (0.0161).

Replicating Tables 4 and 5 with a Wooldridge System GMM estimator (Wooldridge 2009) in Tables B6 and B7 in Appendix B does not alter our results in any significant manner. Although we find a significant R&D coefficient for firm-level productivity in the market economy—driven by the high-tech manufacturing, Transportation & Storage, and Other Services sectors—the magnitude of our R&D coefficient (0.00142) is less than one-tenth of our S&D coefficient (0.0166).

Table 4. Intangible Capital and Firm-Level Productivity – LP Estimations for Market Economy, Services and Goods Sectors, Extended Model Specification

	(1) ME 2011-2022	(2) ME 2011-2015	(3) ME 2016-2019	(4) ME 2020-2022	(5) ME 2020-2022	(6) Services 2011-2022	(7) Services 2011-2015	(8) Services 2016-2019	(9) Services 2020-2022	(10) Services 2020-2022	(11) Goods 2011-2022	(12) Goods 2011-2015	(13) Goods 2016-2019	(14) Goods 2020-2022	(15) Goods 2020-2022
Labour	0.491***	0.491***	0.488***	0.494***	0.502***	0.551***	0.558***	0.542***	0.555***	0.563***	0.399***	0.400***	0.400***	0.395***	0.406***
	(48.32)	(56.91)	(39.01)	(40.16)	(37.83)	(36.26)	(32.03)	(29.16)	(25.92)	(22.88)	(39.20)	(29.57)	(30.24)	(25.17)	(24.25)
Materials	0.422***	0.389***	0.412***	0.295***	0.395***	0.315***	0.341***	0.212***	0.329***	0.218***	0.502***	0.487***	0.503***	0.508***	0.484***
	(79.17)	(12.64)	(313.84)	(5.17)	(7.23)	(10.58)	(26.03)	(5.79)	(5.55)	(5.02)	(18.48)	(28.53)	(9.26)	(12.52)	(8.84)
Tangible Capital	0.0752***	0.0452***	0.0691***	-0.0178	0.0627***	0.0570***	0.0693***	0.0795***	0.0753**	0.0461**	0.0534***	0.0427***	0.0490***	0.0625***	0.0495**
	(32.02)	(5.19)	(34.29)	(-0.66)	(2.94)	(4.86)	(14.33)	(4.27)	(2.47)	(2.24)	(4.93)	(5.89)	(3.00)	(5.02)	(2.00)
Research & Development	0.00116	0.00111	0.000762	0.00173	0.00248	0.00348	0.00494*	0.00162	0.00342	0.00490	0.000370	-0.000147	0.000850	0.000601	0.000756
	(1.12)	(0.85)	(0.60)	(1.19)	(1.51)	(1.55)	(1.83)	(0.66)	(1.11)	(1.44)	(0.31)	(-0.11)	(0.59)	(0.34)	(0.46)
Software & Databases	0.0177***	0.0171***	0.0213***	0.0135***	0.0131***	0.0303***	0.0306***	0.0324***	0.0266***	0.0238***	0.00758***	0.00615**	0.0118***	0.00364	0.00472
	(8.40)	(7.34)	(8.27)	(4.52)	(3.83)	(7.88)	(5.77)	(6.19)	(4.90)	(3.56)	(3.58)	(2.55)	(3.94)	(1.18)	(1.51)
Firm-Specific Human Capital	0.0203***	0.0209***	0.0211***	0.0178***	0.0160***	0.0208***	0.0194***	0.0236***	0.0186***	0.0135**	0.0171***	0.0182***	0.0168***	0.0156***	0.0157***
	(9.24)	(6.93)	(6.90)	(4.98)	(4.87)	(4.14)	(3.40)	(3.91)	(2.71)	(2.23)	(6.02)	(6.76)	(5.83)	(4.91)	(4.30)
Brand Value	0.00579***	0.00622***	0.00658***	0.00419*	0.00556**	0.00917***	0.0118***	0.0111***	0.00132	0.00553	0.00468**	0.00410**	0.00429*	0.00693***	0.00676**
	(3.45)	(3.40)	(3.18)	(1.65)	(2.27)	(2.65)	(2.87)	(2.75)	(0.30)	(1.05)	(2.57)	(2.23)	(1.73)	(2.83)	(2.44)
Covid					0.0639***					0.0783***					0.0470**
					(3.10)					(3.49)					(2.19)
No. of Firms x Years	66,599	28,789	23,062	14,748	13,731	26,655	11,253	9,335	6,067	5,658	39,944	17,536	13,727	8,681	8,073

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table 5. Intangible Capital and Firm-Level Productivity – LP Estimations for Services and Goods Sub-Sectors, Extended Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Goods Total	Manufacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.399***	0.395***	0.410***	0.411***	0.388***	0.402***	0.551***	0.486***	0.438***	0.674***	0.676***	0.488***
	(39.38)	(34.77)	(22.35)	(19.68)	(16.97)	(14.98)	(40.48)	(9.41)	(10.80)	(20.03)	(29.20)	(14.92)
Materials	0.514***	0.501***	0.437***	0.502***	0.521***	0.453***	0.330***	0.439***	0.228***	0.284***	0.163***	0.326***
	(204.41)	(66.03)	(10.16)	(24.52)	(12.23)	(67.03)	(25.92)	(10.28)	(4.17)	(15.07)	(5.99)	(27.50)
Tangible Capital	0.0686***	0.0354***	0.0220	0.0479***	0.0576***	0.0515***	0.0735***	0.0518***	0.0542***	0.0164*	0.0432***	0.0934***
	(30.04)	(11.92)	(1.60)	(8.87)	(4.60)	(11.73)	(29.81)	(4.22)	(2.66)	(1.92)	(3.56)	(22.75)
Research & Development	0.000370	0.00137	0.00301	0.000756	0.0000784	-0.00675**	0.00348*	-0.00175	0.0164***	-0.00265	-0.00369	0.0161***
	(0.35)	(1.17)	(1.34)	(0.52)	(0.03)	(-1.96)	(1.68)	(-0.31)	(3.12)	(-0.52)	(-1.19)	(2.66)
Software & Databases	0.00758***	0.00874***	0.00795**	0.00659**	0.0132***	0.00576	0.0303***	0.0227**	0.0270**	0.0216**	0.0263***	0.0388***
	(3.40)	(3.45)	(2.24)	(2.05)	(3.20)	(0.98)	(8.13)	(2.16)	(2.45)	(2.46)	(3.61)	(4.42)
Firm-Specific Human Capital	0.0171***	0.0181***	0.0199***	0.0135***	0.0150***	0.0113*	0.0208***	-0.0205*	0.0314**	0.0297***	0.0217***	0.0300***
	(7.43)	(7.47)	(4.68)	(4.01)	(3.68)	(1.72)	(4.93)	(-1.95)	(2.34)	(3.36)	(3.05)	(2.91)
Brand Value	0.00468***	0.00338*	0.00389	0.00148	0.00137	0.00636	0.00917***	0.0110	-0.0123*	0.0161*	0.00356	0.0137*
	(2.65)	(1.84)	(1.51)	(0.47)	(0.39)	(1.36)	(2.83)	(1.06)	(-1.79)	(1.93)	(0.75)	(1.68)
No. of Firms x Years	39,944	32,432	11,853	12,123	8,456	7,512	26,655	3,393	3,981	4,441	9,000	5,840

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.

5.3. Separating by Size of R&D and S&D Capital Stocks

Given the fact that the most recent literature highlighted significant right-skewed distributions[3] of intangibles for the US, and the Euro Area economies Germany, France and Austria (De Ridder 2024, Bessen and Wang 2024, Le Mouel and Schiersch 2024, Kaus et al. 2024, Friesenbichler et al. 2025), we run separate estimations for firms with very high R&D and S&D capital stocks (top 20% of the distribution) and all other firms (lowest 80% of the distribution).Tables 6 (top 20%) and 7 (lowest 80%) report the results of the R&D split models for the whole market economy, services and goods production, and the 10 sub-sectors. For the top-20%-R&D firms, we find a highly significant coefficient with a much larger magnitude of 0.0401 for R&D on firm-level productivity, which is strongly driven by high-tech manufacturing (0.0542). Whereas S&D is only significant in the IC sector, we find HC to be significant throughout the whole manufacturing sector.

When looking at the firms with the lowest 80% of R&D capital stock (Table 7), both for the full sample and for services and goods production, no significant impact of R&D on firm-level productivity is found.[4] The only sub-sector that shows a significant coefficient is transportation & storage, with a smaller coefficient of 0.0151. In contrast to the results for the top 20%, we find significant positive effects of S&D and HC for all sectors, though S&D is much stronger in services (0.0301) than in goods production (0.00827).

When analysing the Top 20% with respect to the S&D capital stock (Table 8), we find somewhat different results. Similar to R&D, we find a much higher impact of S&D (0.0539) on firm-level productivity among the top 20% firms, which is strongly driven by services (0.0966) and less so by goods production (0.0341). Moreover, we find HC again to be significant throughout the whole manufacturing sector. Unlike R&D, S&D remains a significant driver of productivity (0.0162) for the lowest 80% of S&D firms (Table 9). At the same time, we find that HC remains significant across the entire manufacturing sector.

Overall, we find that while R&D is only important for the Top 20% R&D firms, S&D and HC impact firm-level productivity throughout the whole economy in the lowest 80% of firms, with S&D being somewhat more important for services, and HC more important for manufacturing.

[3] Bessen and Wang (2024) find the most right-skewed distribution, showing for the US that the top 250 firms ranked by intangible investment have an 83% share of R&D and an 85% share of own account software. Similar to the authors, we find that the top 1% of R&D firms hold 87% of R&D stocks and the top 1% of S&D firms hold 82% of S&D capital stocks (see here Table E1 in Appendix E). However, in contrast to Bessen and Wang (2024) and other existing literature (Kaus et al, 2024; Friesenbichler et al., 2025) who show that a large quantity of firms do not invest in intangibles at all, almost all firms in our sample invest in S&D (92%), HC (90%) and BV (88%) (see here Appendix D and Table E2 in Appendix E..

[4] For a complete replication of Tables 2-5 see the econometric results in Tables B7-14 in Appendix B.

Table 6. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% R&D firms, Extended Model Specification.

	(1) ME	(2) Goods Total	(3) Services Total	(4) Manufacturing Total	(5) High-Tech	(6) Medium-Tech	(7) Low-Tech	(8) Other Goods	(9) Wholesale & Retail Trade	(10) Transportation & Storage	(11) IC	(12) Professional Services	(13) Other Services
Labour	0.369***	0.312***	0.521***	0.328***	0.347***	0.319***	0.281***	0.162	0.163	0.234**	0.738***	0.670***	0.492***
	(16.29)	(19.00)	(9.14)	(18.18)	(12.97)	(9.31)	(6.52)	(1.59)	(0.61)	(2.19)	(9.20)	(7.78)	(4.17)
Materials	0.497***	0.500***	0.327***	0.506***	0.479***	0.550***	0.557***	0.572***	0.894***	0.435***	0.226***	0.218***	0.303***
	(186.16)	(57.73)	(8.68)	(111.52)	(38.07)	(285.88)	(12.17)	(25.91)	(13.02)	(3.74)	(8.14)	(8.57)	(7.58)
Tangible Capital	0.0569***	0.0120	0.0391**	0.0223***	-0.00431	0.0480***	0.0872***	0.0770*	-0.113**	0.0463	0.00795	0.0389*	0.00241
	(16.24)	(1.51)	(2.35)	(4.56)	(-0.50)	(7.02)	(6.75)	(1.85)	(-2.56)	(0.96)	(0.57)	(1.70)	(0.08)
Research & Development	0.0401***	0.0326***	0.0581*	0.0331***	0.0542***	0.0207	-0.0301	0.0554	-0.142	0.0985	0.0544	-0.0161	0.0193
	(4.02)	(4.44)	(1.93)	(4.63)	(5.07)	(1.62)	(-1.27)	(1.11)	(-0.96)	(1.56)	(1.02)	(-0.27)	(0.42)
Software & Databases	0.00874*	0.00536	0.0360**	0.00361	0.00249	0.00278	0.00423	0.0186	-0.00468	-0.0191	0.0394**	0.0111	0.0945
	(1.80)	(1.45)	(1.99)	(1.02)	(0.47)	(0.35)	(0.47)	(0.92)	(-0.03)	(-0.39)	(1.97)	(0.41)	(1.61)
Firm-Specific Human Capital	0.0293***	0.0296***	0.0115	0.0303***	0.0256***	0.0400***	0.0361**	0.0300	-0.0833	-0.0707	0.00167	0.0176	0.0228
	(4.52)	(4.51)	(0.53)	(5.27)	(2.80)	(3.34)	(2.04)	(1.22)	(-0.90)	(-0.63)	(0.06)	(0.33)	(0.22)
Brand Value	0.00671**	0.00791**	-0.00180	0.00942***	0.00406	0.0120**	0.0169**	-0.00301	-0.109	0.0463	-0.00377	0.0282	-0.0141
	(2.07)	(2.50)	(-0.15)	(3.18)	(0.91)	(2.28)	(2.20)	(-0.19)	(-0.83)	(0.76)	(-0.20)	(1.06)	(-0.19)
No. of Firms x Years	10,543	8,793	1,750	8,476	5,410	2,160	906	317	95	154	830	338	333

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table 7. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% R&D firms, Extended Model Specification.

	(1) ME	(2) Goods Total	(3) Services Total	(4) Manufacturing Total	(5) High-Tech	(6) Medium-Tech	(7) Low-Tech	(8) Other Goods	(9) Wholesale & Retail Trade	(10) Transportation & Storage	(11) IC	(12) Professional Services	(13) Other Services
Labour	0.514***	0.423***	0.559***	0.421***	0.441***	0.446***	0.398***	0.415***	0.491***	0.470***	0.652***	0.677***	0.495***
	(38.02)	(32.04)	(40.07)	(27.82)	(21.05)	(22.51)	(26.56)	(13.61)	(8.64)	(13.95)	(24.20)	(28.61)	(16.81)
Materials	0.411***	0.507***	0.295***	0.509***	0.517***	0.482***	0.517***	0.467***	0.455***	0.343***	0.287***	0.179***	0.300***
	(260.99)	(201.16)	(19.73)	(15.71)	(25.14)	(19.94)	(12.17)	(386.07)	(4.87)	(10.41)	(13.54)	(10.89)	(15.95)
Tangible Capital	0.0744***	0.0679***	0.0532***	0.0475***	0.0543***	0.0281***	0.0530***	0.0749***	0.0776***	0.0514***	0.0198*	0.0370***	0.0756***
	(27.05)	(34.89)	(9.69)	(2.87)	(11.36)	(3.63)	(4.45)	(59.42)	(6.18)	(5.40)	(1.84)	(5.61)	(17.01)
Research & Development	-0.000308	-0.00160	0.00135	0.000616	-0.00132	0.00130	0.00140	-0.0110***	0.00166	0.0151***	-0.00667	-0.00350	0.0105*
	(-0.31)	(-1.37)	(0.53)	(0.38)	(-0.40)	(0.68)	(0.60)	(-2.60)	(0.41)	(2.60)	(-1.30)	(-1.00)	(1.91)
Software & Databases	0.0192***	0.00827***	0.0301***	0.0103***	0.00985**	0.00735*	0.0144***	0.00521	0.0221***	0.0312***	0.0164**	0.0267***	0.0382***
	(6.67)	(3.90)	(9.87)	(3.71)	(2.14)	(1.95)	(4.09)	(0.87)	(2.63)	(3.48)	(1.99)	(5.35)	(4.86)
Firm-Specific Human Capital	0.0181***	0.0143***	0.0207***	0.0147***	0.0143**	0.0112***	0.0146***	0.0106	-0.0197*	0.0314***	0.0308***	0.0218***	0.0292**
	(7.38)	(5.64)	(4.72)	(4.98)	(2.38)	(3.25)	(3.34)	(1.39)	(-1.84)	(3.10)	(3.20)	(3.90)	(2.46)
Brand Value	0.00562***	0.00349**	0.00933***	0.00114	0.00299	-0.000505	-0.000523	0.00845**	0.0121	-0.0125*	0.0209**	0.00326	0.0149**
	(3.11)	(2.14)	(4.22)	(0.51)	(1.10)	(-0.19)	(-0.13)	(2.39)	(1.10)	(-1.80)	(2.39)	(0.63)	(2.55)
No. of Firms x Years	56,056	31,151	24,905	23,956	6,443	9,963	7,550	7,195	3,298	3,827	3,611	8,662	5,507

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table 8. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% S&D firms, Extended Model Specification.

	(1) ME	(2) Goods Total	(3) Services Total	(4) Manufacturing Total	(5) High-Tech	(6) Medium-Tech	(7) Low-Tech	(8) Other Goods	(9) Wholesale & Retail Trade	(10) Transportation & Storage	(11) IC	(12) Professional Services	(13) Other Services
Labour	0.361***	0.261***	0.456***	0.277***	0.342***	0.280***	0.179***	0.198***	0.463***	0.207**	0.677***	0.720***	0.514***
	(20.25)	(12.09)	(12.12)	(13.28)	(10.42)	(7.15)	(4.59)	(3.78)	(5.08)	(2.33)	(8.46)	(9.65)	(7.78)
Materials	0.478***	0.530***	0.393***	0.578***	0.515***	0.626***	0.642***	0.477***	0.615***	0.405***	0.343***	0.169***	0.333***
	(177.06)	(123.01)	(11.17)	(65.60)	(16.97)	(199.81)	(70.17)	(8.55)	(7.44)	(5.40)	(4.83)	(6.63)	(10.76)
Tangible Capital	0.0620***	0.0382***	0.0459***	0.0599***	0.0288**	0.0583***	0.0945***	0.0653***	0.0157	0.0680**	0.000741	0.0404**	0.0609***
	(27.21)	(11.10)	(4.63)	(41.02)	(2.29)	(20.89)	(9.38)	(3.68)	(0.41)	(1.98)	(0.03)	(2.30)	(3.39)
Research & Development	0.00385	0.00181	0.00746	-0.00119	-0.0000831	-0.00835*	-0.000492	0.00850	-0.00861	0.00959	-0.000241	-0.00502	0.0287***
	(1.39)	(0.68)	(1.46)	(-0.39)	(-0.02)	(-1.70)	(-0.11)	(1.57)	(-0.98)	(1.12)	(-0.02)	(-0.49)	(2.96)
Software & Databases	0.0539***	0.0341***	0.0966***	0.0285***	0.0342***	0.0333*	0.0209	0.0488	0.0940**	0.129**	0.0969*	0.00433	0.0885**
	(5.08)	(3.23)	(4.18)	(3.02)	(2.81)	(1.67)	(0.86)	(1.13)	(2.47)	(2.13)	(1.69)	(0.08)	(2.49)
Firm-Specific Human Capital	0.0202**	0.0293***	-0.0101	0.0260***	0.0225**	0.0373***	0.0236	0.0976**	-0.0342	0.000652	0.00241	-0.0265	-0.0136
	(2.56)	(4.75)	(-0.71)	(3.65)	(2.46)	(2.84)	(1.42)	(2.40)	(-1.21)	(0.02)	(0.08)	(-0.87)	(-0.37)
Brand Value	0.0105***	0.00852*	0.0210***	0.00900**	0.00759*	0.00537	0.0316***	0.00938	0.0166	0.0226	0.0224	0.0358**	0.0124
	(2.79)	(1.90)	(2.79)	(2.21)	(1.69)	(0.60)	(3.21)	(0.81)	(0.54)	(1.27)	(1.09)	(2.01)	(0.65)
No. of Firms x Years	9,900	6,529	3,371	5,356	2,895	1,548	913	1,173	460	516	784	521	1,090

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table 9. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% S&D firms, Extended Model Specification.

	(1) ME	(2) Goods Total	(3) Services Total	(4) Manufacturing Total	(5) High-Tech	(6) Medium-Tech	(7) Low-Tech	(8) Other Goods	(9) Wholesale & Retail Trade	(10) Transportation & Storage	(11) IC	(12) Professional Services	(13) Other Services
Labour	0.526***	0.441***	0.571***	0.436***	0.452***	0.445***	0.425***	0.452***	0.508***	0.501***	0.667***	0.676***	0.487***
	(43.39)	(38.99)	(27.64)	(41.03)	(26.30)	(20.15)	(16.95)	(15.15)	(8.01)	(9.84)	(17.85)	(32.81)	(13.00)
Materials	0.408***	0.502***	0.290***	0.481***	0.485***	0.465***	0.525***	0.430***	0.448***	0.201***	0.279***	0.267***	0.292***
	(157.44)	(173.68)	(30.55)	(138.99)	(114.87)	(18.86)	(359.89)	(162.42)	(6.10)	(3.78)	(10.43)	(70.38)	(24.71)
Tangible Capital	0.0749***	0.0668***	0.0452***	0.0268***	0.0220***	0.0254*	0.0707***	0.0404***	0.0852***	0.00892	0.0267***	0.0837***	0.0742***
	(48.12)	(37.56)	(7.95)	(7.28)	(6.44)	(1.71)	(64.35)	(9.79)	(3.86)	(0.49)	(2.65)	(28.41)	(15.74)
Research & Development	0.00128*	0.00107	0.00167	0.00233**	0.00428*	0.00202	-0.000884	-0.00962**	0.00222	0.0209***	-0.00338	-0.00402	0.00855
	(1.76)	(1.06)	(0.80)	(2.04)	(1.73)	(1.23)	(-0.37)	(-2.47)	(0.29)	(2.70)	(-0.61)	(-1.33)	(1.36)
Software & Databases	0.0162***	0.00621***	0.0271***	0.00934***	0.0102***	0.00574*	0.0143***	-0.00175	0.0197	0.0267**	0.0166	0.0259***	0.0380***
	(7.66)	(2.73)	(5.91)	(3.58)	(2.81)	(1.92)	(2.86)	(-0.35)	(1.36)	(2.03)	(1.60)	(4.93)	(3.93)
Firm-Specific Human Capital	0.0193***	0.0148***	0.0236***	0.0159***	0.0183***	0.0117***	0.0152***	0.00922	-0.0183	0.0369**	0.0303***	0.0236**	0.0328***
	(8.57)	(4.88)	(3.93)	(6.73)	(2.61)	(2.69)	(2.81)	(1.34)	(-1.32)	(2.16)	(3.12)	(2.42)	(3.60)
Brand Value	0.00497***	0.00370**	0.00729**	0.00272	0.00459	0.000963	-0.000536	0.00319	0.0101	-0.0174**	0.0163***	0.00204	0.0129
	(2.88)	(2.48)	(2.02)	(1.34)	(1.56)	(0.32)	(-0.12)	(0.69)	(0.82)	(-2.41)	(2.58)	(0.48)	(1.62)
No. of Firms x Years	56,699	33,415	23,284	27,076	8,958	10,575	7,543	6,339	2,933	3,465	3,657	8,479	4,750

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

5.4. Discussion in Light of Previous Studies

Our findings extend the existing literature on the role of intangibles for firm-level productivity in several ways. First, our results confirm basic findings of the literature with respect to the positive productivity impact of the two intangible assets that are captured in national accounts - R&D and S&D (Kaus et al. 2024, Friesenbichler et al. 2025, Roth et al. 2023). We complement this literature by finding a much stronger impact of S&D than of R&D during the time period covered in this study (2011-2022).

However, this result only holds as long as only R&D and S&D are taken into account. As soon as other firm-specific investment in human capital and investment in brand value is included, these non-national accounts intangibles clearly change the results. In such an extended production function, R&D becomes insignificant for the whole economy and all major sub-sectors, including high-tech manufacturing. In contrast, the non-R&D intangibles S&D and HC become the dominant drivers of firm-level productivity, with HC having the strongest impact.

This general finding has to be differentiated when one takes into account the right-skewed distribution of intangibles. Both for R&D and S&D, a very large share of intangible capital stocks is concentrated among a small group of firms, while the vast majority of firms operates with very small stocks of intangible assets or even have capital stocks of zero for R&D. When considering the top 20% firms in terms of R&D and S&D capital stocks, respectively, we find that these firms have higher coefficients for both R&D and S&D as compared to firms with the lowest 80% of R&D and S&D capital stocks. This result is in line with the literature (Le Mouel and Schiersch 2024, Kaus et al. 2024, De Ridder 2024).

However, for R&D, in line with results by Roth et. al (2023), Kumbhakar et al. (2012) and Ortega-Argilés et al. (2015) we find that firms from high-tech manufacturing mainly drive this result. In almost all other industries, among the top 20%, as well as among all firms in the lower 80% R&D shows no positive impact on productivity. For S&D, we find that this intangible asset has a positive effect across the whole economy, both for the top 20% and the lowest 80% of firms. Our results, therefore, complement the findings by Le Mouel and Schiersch (2024), who analyse an aggregate of intangible capital and are unable to differentiate between R&D and Software capital stocks in Germany.

In addition, we complement all of the existing literature by showing that HC plays an important role even when differentiating between the size of capital stocks, highlighting the critical role of skills in the age of digitalisation (Mattsson and Reshid 2023).

6. Implications for Research Policy

We believe that our findings have several implications for designing government policies that aim at enhancing productivity by strengthening firms' investment into knowledge and other intangible assets. So far, governments often focus on R&D, arguing that R&D generates positive externalities through knowledge spillovers, and legitimating public support for R&D by private underinvestment due to these spillovers (Arora et al. 2021, Aghion and Jaravel 2015, Becker 2015). Support for other investments in intangible assets, such as computerised knowledge, firm-specific human capital, or brand value, receives far less government attention, as the argument for positive externalities is less convincing. This can be seen, for example, from EU regulations, which allow substantial government subsidies to firms for R&D, but not for other intangible investments.

Our findings suggest that other types of intangibles than R&D also have substantial, and often much larger impacts on firm-level productivity, particularly with regard to S&D and HC. This result can be linked to the ongoing transformation towards a digital economy and a knowledge economy that exploits various types of knowledge to produce more efficiently and offer goods and services of higher quality and novelty. In this process, computerised information contained in software routines and databases (including artificial intelligence applications) is becoming more and more important, as is complementary intangible capital such as firm-specific competencies of employees. These types of knowledge capital constitute new and increasingly important sources for productivity gains. The large productivity impact we find for both S&D and HC indicates that, in the early stages of such a transition, firms that invested early and broadly in these knowledge sources can gain a competitive advantage and outperform firms that are more reluctant to invest in these intangible assets. The weak and often insignificant contribution of R&D to firm-level productivity may be attributed to various reasons. On the one hand, it may reflect difficulties in avoiding unintended knowledge spillovers, i.e., patent protection and other measures to limit the use of own R&D results by other firms are not strong enough or cannot be protected adequately. As a result, productivity gains from a firm's R&D efforts mainly accrue to competitors, but not to the R&D-performing firm. This interpretation is substantiated by analyses at the industry level, which reveal positive productivity impacts of R&D across most industries, suggesting that firms in these industries do not profit as much from their own R&D investment as from R&D results generated by other firms.

On the other hand, R&D investment outside of high-tech industries may be too low to generate substantial productivity impacts, e.g., because firms outside high-tech face more difficulties in obtaining the resources required for R&D (high-skilled staff, venture capital, university cooperation). If both arguments apply, they can reinforce each other, since limited appropriability results in lower private investment. In the German context, there are some indications that such a situation may be in place, since most R&D in the business enterprise sector is performed in high-tech manufacturing (2021: 86.6%), while most other industries spend rather little on R&D, and show an R&D intensity below the OECD average in their industry.

A third argument that could be brought forward is that digitalisation has reduced the value of R&D results that are not related to digitalisation, which would lower the productivity contribution of R&D. In addition, a likely positive effect of digitalisation-oriented R&D may be captured by the S&D capital stock, leaving R&D with a low (insignificant) productivity impact. We believe that this argument is very plausible for services, as innovation activities there are very strongly associated with digital approaches. It is less convincing for low-tech manufacturing, where digitalisation plays only a minor role.

The implications of our findings for research policy depend on how we interpret the weak findings of R&D on firm-level productivity. In case high knowledge spillovers drive the results, the primary policy concern should be to provide sufficient incentives for firms to perform R&D to keep the spillover mechanism working. This could be done by subsidising R&D through tax incentive schemes. Such schemes can easily be designed in a way that they reach out to all R&D performing firms and provide incentives for various types of R&D activities (see Laredo et al. 2016). In case limited R&D appropriability is responsible for low productivity impacts, a more effective IP regime or a better use of the existing IP regime would be needed. The degree of novelty of R&D results as compared to the existing stock of knowledge is often low, and expected additional returns from R&D are limited (as the financial effort to conduct such R&D is limited). In this situation, the high cost of using patents as an IP protection mechanism (both for the application process and for monitoring and addressing IP violations) may deter many firms from using the patent system. In addition, smaller firms may lack the knowledge and resources to use patents effectively as a protection mechanism (see Crass et al. 2019b). Research policy can address these issues by providing dedicated support to firms outside of the high-tech industry when using patents, e.g., by subsidising patent application costs.

With respect to the significant contribution of investment in S&D and HC for productivity gains, governments could spur such investment through different approaches. On the one hand, one may argue in favour of government subsidies for such investment in a similar way as is done for R&D, as unintended spillovers to competitors may occur in a similar way as for R&D. In case of S&D, patent law limits the possibility to protect new software routines through patents while many software applications require a certain degree of openness in terms of codes and software routines in order to enable compatibility with complementary applications (Fersthman and Gandal 2011). In case of training of employees, the departure of employees to other firms means the outflow of investments made in further training to competitors. Empirical studies show that this is a major source of unintended knowledge spillovers (Kraft and Rammer 2023) and is likely to lead to an underinvestment in training.

However, general government subsidies to all kinds of S&D and HC investments are likely to be ineffective, costly, and potentially distorting competition since many S&D and HC investments may not be subject to knowledge spillovers. Indirect support measures, including preferential tax treatment, an effective education system that supplies firms with the (IT-related) skills they need, and a legal and technical infrastructure to enable effective investment, are useful tools for governments to broaden positive productivity impacts of S&D and HC.

7. Conclusion

Using a unique large firm-level dataset for Germany for the time period 2011-2022, we find a significant impact of non-R&D intangibles, including software and databases and firm-specific human capital on firm-level productivity in Germany. This impact is stronger in the German service sector than in its goods-producing sector. Research and Development is only significantly related to productivity in the high-tech manufacturing sector, and here only among those firms with the Top 20% largest capital stocks in R&D.

The policy implications of our research findings are twofold. First, we promote stronger public funding of R&D, also outside the high-tech. manufacturing sector and among those firms already endowed with large R&D capital stocks. Second, the promotion of investment incentives and framework conditions for non-R&D intangibles, including software and databases and complementary intangibles, including firm-specific human capital, is central to stimulating firm-level productivity throughout all sectors and, respectively, for the whole market economy.

The existing competitiveness policies, such as those discussed in the Draghi (2024) report for the EU, as well as most national schemes and initiatives, strongly focus on R&D activities to strengthen innovation and competitiveness and often target the manufacturing sector. To stimulate firm-level productivity across the whole market economy, the focus on investment in non-R&D intangibles, including software and firm-specific human capital — particularly in the service sector — should complement the existing competitiveness strategy.

While our study is the first one to analyse firm-level productivity impacts of four types of intangibles over time, it has a number of limitations that should be addressed in future research. One limitation is the rather short time period and the lack of very current data that would represent recent changes in intangible investment triggered by new opportunities such as artificial intelligence (AI). A growing literature suggests that this type of S&D investment results in high productivity gains (Czarnitzki et al. 2023, Fontanelli et al. 2025, Filippucci 2024, Da Silva Marioni et al. 2024), which may further shift the productivity impacts of intangibles towards S&D. Fresh data from the 2025 wave of the Innovation Survey will allow us to analyse such changes.

Another limitation is the lack of capital stock data on firm-specific organisational capital, which should be tackled by future research, though measuring organisational capital is challenging (Trunschke et al. 2020). Finally, the results of the present paper are confined to the situation in Germany. Comparative studies for other countries could substantially deepen our understanding of the way intangible assets drive productivity in firms.

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Appendix A. Additional Summary Statistics

Table A1. Summary statistics of model variables, goods, services, and sub-sectors

Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	39,944	94.704	1037.334	0.0149	77068.92
Intermediary input (million Euro)	39,944	59.870	755.555	0.000513	64405.16
Labour (head count)	39,944	272.220	1792.842	1	94924.4
Tangible capital stock (million Euro)	39,944	59.895	634.444	0.000296	37468.55
Investment in research & development (million Euro)	39,944	21.085	383.276	0	29881.95
Investment in firm specific human capital (million Euro)	39,944	0.932	11.832	0	973.401
Investment in brand value (million Euro)	39,944	9.897	256.786	0	22268.74
Investment in software & databases (million Euro)	39,944	1.918	24.754	0	1709.513
Covid	39,336	-0.121	0.510	-3	2

Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	32,432	97.775	1128.485	0.023	77068.92
Intermediary input (million Euro)	32,432	61.331	820.677	0.00102	64405.16
Labour (head count)	32,432	292.490	1929.994	1	94924.4
Tangible capital stock (million Euro)	32,432	48.197	617.754	0.000296	37468.55
Investment in research & development (million Euro)	32,432	25.626	424.847	0	29881.95
Investment in firm specific human capital (million Euro)	32,432	1.024	13.039	0	973.401
Investment in brand value (million Euro)	32,432	11.782	284.889	0	22268.74
Investment in software & databases (million Euro)	32,432	2.016	26.604	0	1709.513
Covid	31,948	-0.134	0.541	-3	2

Hich tech manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	11,853	190.032	1831.131	0.0285	77068.92
Intermediary input (million Euro)	11,853	121.028	1332.607	0.00407	64405.16
Labour (head count)	11,853	500.338	3011.220	1	94924.4
Tangible capital stock (million Euro)	11,853	97.185	992.601	0.000634	37468.55
Investment in research & development (million Euro)	11,853	63.854	698.147	0	29881.95
Investment in firm specific human capital (million Euro)	11,853	2.078	20.096	0	973.401
Investment in brand value (million Euro)	11,853	26.310	469.068	0	22268.74
Investment in software & databases (million Euro)	11,853	4.440	43.416	0	1709.513
Covid	11,688	-0.133	0.530	-3	2

Medium tech manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	12,123	52.236	322.510	0.023	10271.69
Intermediary input (million Euro)	12,123	31.895	232.824	0.00106	9654.632
Labour (head count)	12,123	193.717	913.123	1	22136.33
Tangible capital stock (million Euro)	12,123	25.774	226.410	0.000296	7238.764
Investment in research & development (million Euro)	12,123	5.357	63.460	0	3090.02
Investment in firm specific human capital (million Euro)	12,123	0.595	7.604	0	399.5009
Investment in brand value (million Euro)	12,123	3.591	37.093	0	1577.541
Investment in software & databases (million Euro)	12,123	0.752	6.128	0	206.2401
Covid	11,907	-0.138	0.516	-3	2

Low tech manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	8,456	33.741	127.957	0.0267	2798.916
Intermediary input (million Euro)	8,456	19.855	91.625	0.00102	2540.726
Labour (head count)	8,456	142.752	533.546	1	11814
Tangible capital stock (million Euro)	8,456	11.677	61.355	0.000845	1572.525
Investment in research & development (million Euro)	8,456	1.100	8.789	0	269.5357
Investment in firm specific human capital (million Euro)	8,456	0.161	0.753	0	22.65845
Investment in brand value (million Euro)	8,456	3.159	21.191	0	526.4985
Investment in software & databases (million Euro)	8,456	0.430	2.382	0	66.06615
Covid	8,353	-0.131	0.589	-3	2

Other Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	7,512	81.445	472.847	0.0149	10189.95
Intermediary input (million Euro)	7,512	53.563	357.315	0.000513	8184.329
Labour (head count)	7,512	184.706	1000.322	1	25492
Tangible capital stock (million Euro)	7,512	110.400	699.765	0.000859	15899.36
Investment in research & development (million Euro)	7,512	1.476	37.289	0	2207.876
Investment in firm specific human capital (million Euro)	7,512	0.534	3.188	0	84.5862
Investment in brand value (million Euro)	7,512	1.760	11.754	0	310.4839
Investment in software & databases (million Euro)	7,512	1.495	14.227	0	674.6097
Covid	7,388	-0.061	0.339	-3	2

Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	26,655	81.232	845.585	0.0143	39183.37
Intermediary input (million Euro)	26,655	48.414	509.968	0.000552	22054.4
Labour (head count)	26,655	269.238	3363.005	1	183991
Tangible capital stock (million Euro)	26,655	44.461	1019.453	0.000153	58855.33
Investment in research & development (million Euro)	26,655	4.060	129.718	0	10771.05
Investment in firm specific human capital (million Euro)	26,655	1.030	14.389	0	599.1818
Investment in brand value (million Euro)	26,655	6.939	140.258	0	9779.824
Investment in software & databases (million Euro)	26,655	5.059	140.842	0	10355.07
Covid	26,246	-0.108	0.531	-3	2

Trade

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,393	120.410	670.365	0.0158	7682.654
Intermediary input (million Euro)	3,393	95.463	566.466	0.00423	7316.279
Labour (head count)	3,393	209.126	1503.860	1	26113
Tangible capital stock (million Euro)	3,393	18.307	190.020	0.000845	4096.088
Investment in research & development (million Euro)	3,393	0.379	3.509	0	77.81317
Investment in firm specific human capital (million Euro)	3,393	0.286	2.420	0	92.69587
Investment in brand value (million Euro)	3,393	7.297	141.277	0	5944.139
Investment in software & databases (million Euro)	3,393	1.218	7.913	0	116.5779
Covid	3,334	-0.079	0.569	-3	2

Transport

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,981	112.517	989.505	0.0498	20779.27
Intermediary input (million Euro)	3,981	61.234	597.325	0.000987	14939.55
Labour (head count)	3,981	695.693	7670.388	1	183991
Tangible capital stock (million Euro)	3,981	176.503	2053.583	0.00102	58855.33
Investment in research & development (million Euro)	3,981	1.641	16.302	0	344.1723
Investment in firm specific human capital (million Euro)	3,981	1.780	20.350	0	451.4766
Investment in brand value (million Euro)	3,981	7.905	93.947	0	1996.97
Investment in software & databases (million Euro)	3,981	2.441	21.655	0	428.691
Covid	3,920	-0.145	0.573	-3	2

ICT services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	4,441	82.309	979.859	0.0229	28933.42
Intermediary input (million Euro)	4,441	35.106	403.296	0.000858	14732.12
Labour (head count)	4,441	257.313	3056.044	1	102809
Tangible capital stock (million Euro)	4,441	64.923	1546.725	0.000845	54063.54
Investment in research & development (million Euro)	4,441	18.375	314.650	0	10771.05
Investment in firm specific human capital (million Euro)	4,441	1.655	21.308	0	534.9573
Investment in brand value (million Euro)	4,441	16.331	295.077	0	9779.824
Investment in software & databases (million Euro)	4,441	19.165	338.400	0	10355.07
Covid	4,372	-0.103	0.524	-3	2

Professional services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	9,000	7.845	76.441	0.0143	2156.66
Intermediary input (million Euro)	9,000	2.106	21.854	0.000552	760.6048
Labour (head count)	9,000	65.814	570.314	1	16810
Tangible capital stock (million Euro)	9,000	1.733	20.810	0.000153	589.4814
Investment in research & development (million Euro)	9,000	0.313	3.155	0	164.5553
Investment in firm specific human capital (million Euro)	9,000	0.476	11.897	0	599.1818
Investment in brand value (million Euro)	9,000	0.424	6.161	0	270.0637
Investment in software & databases (million Euro)	9,000	0.287	2.356	0	75.56844
Covid	8,865	-0.095	0.472	-3	2

Other services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	5,840	149.422	1257.720	0.0296	39183.37
Intermediary input (million Euro)	5,840	93.827	791.351	0.000818	22054.4
Labour (head count)	5,840	336.021	1553.306	1	36742
Tangible capital stock (million Euro)	5,840	19.934	113.054	0.000253	2983.029
Investment in research & development (million Euro)	5,840	2.738	33.652	0	1218.915
Investment in firm specific human capital (million Euro)	5,840	1.331	9.724	0	290.737
Investment in brand value (million Euro)	5,840	8.972	76.057	0	2126.281
Investment in software & databases (million Euro)	5,840	5.705	53.929	0	2377.917
Covid	5,755	-0.122	0.566	-3	2

Table A2. Summary statistics of model variables, goods, services and sub-sectors – Top 20% R&D firms

Total

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	13,320	356.615	2101.244	0.1857	77068.92
Intermediary input (million Euro)	13,320	219.479	1443.290	0.023828	64405.16
Labour (head count)	13,320	1003.419	5559.262	1	183991
Tangible capital stock (million Euro)	13,320	219.961	1769.050	0.000881	58855.33
Investment in research & development (million Euro)	13,320	71.090	685.954	0.7017508	29881.95
Investment in firm specific human capital (million Euro)	13,320	4.216	28.483	0	973.401
Investment in brand value (million Euro)	13,320	38.984	484.653	0	22268.74
Investment in software & databases (million Euro)	13,320	14.136	203.198	0	10355.07

Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	2,482	626.805	2608.073	0.1868	39183.37
Intermediary input (million Euro)	2,482	355.706	1491.682	0.023828	22054.4
Labour (head count)	2,482	1933.740	10815.520	2	183991
Tangible capital stock (million Euro)	2,482	388.428	3299.475	0.000881	58855.33
Investment in research & development (million Euro)	2,482	43.147	423.187	0.7030558	10771.05
Investment in firm specific human capital (million Euro)	2,482	9.004	45.930	0	599.1818
Investment in brand value (million Euro)	2,482	58.645	450.794	0	9779.824
Investment in software & databases (million Euro)	2,482	48.677	458.815	0	10355.07

Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	10,838	294.740	1961.798	0.1857	77068.92
Intermediary input (million Euro)	10,838	188.282	1430.224	0.025342	64405.16
Labour (head count)	10,838	790.367	3310.573	1	94924.4
Tangible capital stock (million Euro)	10,838	181.380	1160.158	0.001090	37468.55
Investment in research & development (million Euro)	10,838	77.489	732.856	0.7017508	29881.95
Investment in firm specific human capital (million Euro)	10,838	3.119	22.531	0	973.401
Investment in brand value (million Euro)	10,838	34.482	491.989	0	22268.74
Investment in software & databases (million Euro)	10,838	6.226	47.074	0	1709.513

Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	10,411	272.663	1975.852	0.185721	77068.92
Intermediary input (million Euro)	10,411	172.495	1438.805	0.02534	64405.16
Labour (head count)	10,411	762.787	3329.326	1	94924.4
Tangible capital stock (million Euro)	10,411	141.039	1083.430	0.001090	37468.55
Investment in research & development (million Euro)	10,411	79.624	747.004	0.7017508	29881.95
Investment in firm specific human capital (million Euro)	10,411	3.025	22.878	0	973.401
Investment in brand value (million Euro)	10,411	35.320	501.929	0	22268.74
Investment in software & databases (million Euro)	10,411	5.890	46.670	0	1709.513

High Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	6,420	340.147	2477.784	0.2072	77068.92
Intermediary input (million Euro)	6,420	217.143	1804.802	0.02534	64405.16
Labour (head count)	6,420	877.034	4052.394	1	94924.4
Tangible capital stock (million Euro)	6,420	176.946	1343.547	0.001090	37468.55
Investment in research & development (million Euro)	6,420	117.745	945.311	0.7019291	29881.95
Investment in firm specific human capital (million Euro)	6,420	3.777	27.191	0	973.401
Investment in brand value (million Euro)	6,420	48.314	636.550	0	22268.74
Investment in software & databases (million Euro)	6,420	8.056	58.748	0	1709.513

Medium Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	2,769	183.442	629.998	0.185721	10271.69
Intermediary input (million Euro)	2,769	114.863	459.695	0.04583	9654.632
Labour (head count)	2,769	647.010	1821.564	6	22136.33
Tangible capital stock (million Euro)	2,769	101.178	463.308	0.013106	7238.764
Investment in research & development (million Euro)	2,769	23.167	131.244	0.7024171	3090.02
Investment in firm specific human capital (million Euro)	2,769	2.341	15.769	0	399.5009
Investment in brand value (million Euro)	2,769	14.419	76.464	0	1577.541
Investment in software & databases (million Euro)	2,769	2.748	12.248	0	206.2401

Low Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,222	120.295	209.125	0.2645	2032.583
Intermediary input (million Euro)	1,222	68.524	132.892	0.07333	1620.185
Labour (head count)	1,222	424.920	659.889	9	5566
Tangible capital stock (million Euro)	1,222	42.716	106.147	0.018584	1321.323
Investment in research & development (million Euro)	1,222	7.277	22.141	0.7017508	269.5357
Investment in firm specific human capital (million Euro)	1,222	0.624	1.492	0	22.65845
Investment in brand value (million Euro)	1,222	14.412	46.636	0	526.4985
Investment in software & databases (million Euro)	1,222	1.632	4.519	0	66.06615

Other Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	427	833.002	1484.270	0.4003	8025.004
Intermediary input (million Euro)	427	573.179	1137.595	0.0587392	6525.828
Labour (head count)	427	1462.806	2733.327	7	20922
Tangible capital stock (million Euro)	427	1164.980	2132.203	0.053539	10849.85
Investment in research & development (million Euro)	427	25.432	154.617	0.7100477	2207.876
Investment in firm specific human capital (million Euro)	427	5.423	10.883	0	84.5862
Investment in brand value (million Euro)	427	14.057	27.659	0	109.4258
Investment in software & databases (million Euro)	427	14.403	55.459	0	674.6097

Trade

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	130	656.933	1667.146	0.4666	7312.07
Intermediary input (million Euro)	130	385.225	1003.266	0.03056	6966.166
Labour (head count)	130	2631.400	7000.731	5	26113
Tangible capital stock (million Euro)	130	262.315	735.136	0.002669	2698.855
Investment in research & development (million Euro)	130	8.966	15.692	0.7267797	77.81317
Investment in firm specific human capital (million Euro)	130	3.396	11.360	0	92.69587
Investment in brand value (million Euro)	130	148.585	708.574	0.041325	5944.139
Investment in software & databases (million Euro)	130	13.040	29.859	0.0162368	116.5779

Transportation

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	204	1783.541	4001.367	0.9785	20779.27
Intermediary input (million Euro)	204	1011.387	2446.624	0.095743	14939.55
Labour (head count)	204	10849.100	32241.810	4	183991
Tangible capital stock (million Euro)	204	2818.233	8590.550	0.01943	58855.33
Investment in research & development (million Euro)	204	31.614	65.260	0.7091835	344.1723
Investment in firm specific human capital (million Euro)	204	30.510	84.936	0	451.4766
Investment in brand value (million Euro)	204	120.636	395.714	0	1996.97
Investment in software & databases (million Euro)	204	39.868	87.341	0	428.691

ICT services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,165	277.987	1896.398	0.1868	28933.42
Intermediary input (million Euro)	1,165	117.541	779.462	0.027633	14732.12
Labour (head count)	1,165	802.527	5916.848	2	102809
Tangible capital stock (million Euro)	1,165	235.071	3013.634	0.000881	54063.54
Investment in research & development (million Euro)	1,165	69.761	611.607	0.7056814	10771.05
Investment in firm specific human capital (million Euro)	1,165	5.737	41.284	0	534.9573
Investment in brand value (million Euro)	1,165	52.422	570.012	0	9779.824
Investment in software & databases (million Euro)	1,165	71.148	658.091	0	10355.07

Professional Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	557	80.936	295.308	0.2365	2156.66
Intermediary input (million Euro)	557	21.699	83.516	0.023828	760.6048
Labour (head count)	557	615.570	2205.754	4	16810
Tangible capital stock (million Euro)	557	22.184	79.931	0.001000	589.4814
Investment in research & development (million Euro)	557	4.261	12.010	0.7030558	164.5553
Investment in firm specific human capital (million Euro)	557	6.526	47.441	0	599.1818
Investment in brand value (million Euro)	557	5.088	24.249	0	270.0637
Investment in software & databases (million Euro)	557	2.682	9.069	0	75.56844

Other Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	426	1731.339	4320.128	0.4575	39183.37
Intermediary input (million Euro)	426	1120.749	2656.429	0.037331	22054.4
Labour (head count)	426	2268.614	5000.827	2	36742
Tangible capital stock (million Euro)	426	161.605	354.401	0.018506	2983.029
Investment in research & development (million Euro)	426	37.160	119.489	0.7068374	1218.915
Investment in firm specific human capital (million Euro)	426	12.589	30.591	0	290.737
Investment in brand value (million Euro)	426	88.558	243.681	0	2126.281
Investment in software & databases (million Euro)	426	62.458	184.269	0	2377.917

Table A3. Summary statistics of model variables, goods, services and sub-sectors – Lower 80% R&D firms

Total

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	53,279	22.485	195.964	0.0143	10189.95
Intermediary input (million Euro)	53,279	14.236	170.147	0.000513	8184.329
Labour (head count)	53,279	87.925	417.346	1	25492
Tangible capital stock (million Euro)	53,279	12.156	175.461	0.000153	15899.36
Investment in research & development (million Euro)	53,279	0.066	0.145	0	0.7017298
Investment in firm specific human capital (million Euro)	53,279	0.160	1.563	0	193.6308
Investment in brand value (million Euro)	53,279	1.145	16.525	0	1380.117
Investment in software & databases (million Euro)	53,279	0.435	5.173	0	622.2153

Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	24,173	25.215	237.851	0.0143	7682.654
Intermediary input (million Euro)	24,173	16.863	218.393	0.000552	7316.279
Labour (head count)	24,173	98.332	388.722	1	9653
Tangible capital stock (million Euro)	24,173	9.143	123.349	0.000153	8100.211
Investment in research & development (million Euro)	24,173	0.047	0.120	0	0.7005817
Investment in firm specific human capital (million Euro)	24,173	0.211	2.143	0	193.6308
Investment in brand value (million Euro)	24,173	1.630	23.054	0	1380.117
Investment in software & databases (million Euro)	24,173	0.581	7.160	0	622.2153

Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	29,106	20.218	152.645	0.0149	10189.95
Intermediary input (million Euro)	29,106	12.055	115.639	0.000513	8184.329
Labour (head count)	29,106	79.281	439.523	1	25492
Tangible capital stock (million Euro)	29,106	14.659	209.061	0.000296	15899.36
Investment in research & development (million Euro)	29,106	0.082	0.161	0	0.7017298
Investment in firm specific human capital (million Euro)	29,106	0.117	0.808	0	60.74053
Investment in brand value (million Euro)	29,106	0.742	7.622	0	524.7737
Investment in software & databases (million Euro)	29,106	0.314	2.527	0	157.8774

Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	22,021	15.091	93.053	0.023	4773.782
Intermediary input (million Euro)	22,021	8.776	68.328	0.00102	4557.549
Labour (head count)	22,021	70.145	302.981	1	11814
Tangible capital stock (million Euro)	22,021	4.304	33.475	0.000296	1579.189
Investment in research & development (million Euro)	22,021	0.097	0.173	0	0.7017298
Investment in firm specific human capital (million Euro)	22,021	0.078	0.414	0	34.46163
Investment in brand value (million Euro)	22,021	0.653	6.895	0	524.7737
Investment in software & databases (million Euro)	22,021	0.184	1.503	0	147.1158

High Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	5,433	12.646	53.765	0.0285	2037.075
Intermediary input (million Euro)	5,433	7.453	41.210	0.00407	1600.916
Labour (head count)	5,433	55.209	111.680	1	2240
Tangible capital stock (million Euro)	5,433	2.935	14.273	0.000634	361.4462
Investment in research & development (million Euro)	5,433	0.173	0.212	0	0.7017298
Investment in firm specific human capital (million Euro)	5,433	0.070	0.257	0	10.55132
Investment in brand value (million Euro)	5,433	0.308	1.241	0	24.63036
Investment in software & databases (million Euro)	5,433	0.166	0.758	0	27.2165

Medium Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	9,354	13.396	103.635	0.023	4773.782
Intermediary input (million Euro)	9,354	7.334	71.233	0.00106	4557.549
Labour (head count)	9,354	59.532	140.788	1	7691
Tangible capital stock (million Euro)	9,354	3.452	27.013	0.000296	1579.189
Investment in research & development (million Euro)	9,354	0.084	0.159	0	0.7016204
Investment in firm specific human capital (million Euro)	9,354	0.079	0.420	0	34.46163
Investment in brand value (million Euro)	9,354	0.386	2.814	0	113.6362
Investment in software & databases (million Euro)	9,354	0.162	1.655	0	147.1158

Low Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	7,234	19.120	101.377	0.0267	2798.916
Intermediary input (million Euro)	7,234	11.633	79.778	0.00102	2540.726
Labour (head count)	7,234	95.086	493.491	1	11814
Tangible capital stock (million Euro)	7,234	6.434	48.043	0.000845	1572.525
Investment in research & development (million Euro)	7,234	0.057	0.135	0	0.7008875
Investment in firm specific human capital (million Euro)	7,234	0.082	0.495	0	17.7737
Investment in brand value (million Euro)	7,234	1.258	11.523	0	524.7737
Investment in software & databases (million Euro)	7,234	0.227	1.703	0	56.76553

Other Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	7,085	36.150	261.688	0.0149	10189.95
Intermediary input (million Euro)	7,085	22.247	200.727	0.000513	8184.329
Labour (head count)	7,085	107.677	712.238	1	25492
Tangible capital stock (million Euro)	7,085	46.842	417.992	0.000859	15899.36
Investment in research & development (million Euro)	7,085	0.033	0.100	0	0.7013274
Investment in firm specific human capital (million Euro)	7,085	0.239	1.459	0	60.74053
Investment in brand value (million Euro)	7,085	1.019	9.530	0	310.4839
Investment in software & databases (million Euro)	7,085	0.717	4.358	0	157.8774

Trade

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,263	99.034	587.755	0.0158	7682.654
Intermediary input (million Euro)	3,263	83.918	538.876	0.00423	7316.279
Labour (head count)	3,263	112.621	412.799	1	8753
Tangible capital stock (million Euro)	3,263	8.585	117.079	0.000845	4096.088
Investment in research & development (million Euro)	3,263	0.037	0.108	0	0.6967882
Investment in firm specific human capital (million Euro)	3,263	0.162	0.767	0	16.12224
Investment in brand value (million Euro)	3,263	1.668	8.487	0	156.5364
Investment in software & databases (million Euro)	3,263	0.747	4.905	0	115.8995

Transportation

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,777	22.263	110.702	0.0498	3380.181
Intermediary input (million Euro)	3,777	9.915	53.443	0.000987	1613.592
Labour (head count)	3,777	147.296	507.008	1	9653
Tangible capital stock (million Euro)	3,777	33.820	283.275	0.00102	8100.211
Investment in research & development (million Euro)	3,777	0.023	0.084	0	0.6999751
Investment in firm specific human capital (million Euro)	3,777	0.228	1.281	0	30.10101
Investment in brand value (million Euro)	3,777	1.817	12.685	0	242.868
Investment in software & databases (million Euro)	3,777	0.419	2.095	0	65.04747

ICT services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,276	12.723	70.672	0.0229	1129.023
Intermediary input (million Euro)	3,276	5.791	35.915	0.000858	562.7219
Labour (head count)	3,276	63.426	274.588	1	5245
Tangible capital stock (million Euro)	3,276	4.415	38.725	0.000845	883.309
Investment in research & development (million Euro)	3,276	0.101	0.171	0	0.6988009
Investment in firm specific human capital (million Euro)	3,276	0.203	1.326	0	35.83231
Investment in brand value (million Euro)	3,276	3.496	43.984	0	1375.595
Investment in software & databases (million Euro)	3,276	0.679	4.576	0	150.6372

Professional Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	8,443	3.023	10.465	0.0143	310.6539
Intermediary input (million Euro)	8,443	0.813	4.770	0.000552	166.9377
Labour (head count)	8,443	29.546	70.876	1	1350
Tangible capital stock (million Euro)	8,443	0.384	3.383	0.000153	281.8238
Investment in research & development (million Euro)	8,443	0.052	0.123	0	0.7005817
Investment in firm specific human capital (million Euro)	8,443	0.076	0.243	0	7.82391
Investment in brand value (million Euro)	8,443	0.117	0.460	0	12.37972
Investment in software & databases (million Euro)	8,443	0.129	0.309	0	7.520242

Other Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	5,414	24.950	168.979	0.0296	6114.765
Intermediary input (million Euro)	5,414	13.024	178.742	0.000818	5220.46
Labour (head count)	5,414	183.955	567.504	1	9500
Tangible capital stock (million Euro)	5,414	8.786	47.135	0.000253	1216.427
Investment in research & development (million Euro)	5,414	0.029	0.091	0	0.6899761
Investment in firm specific human capital (million Euro)	5,414	0.445	4.215	0	193.6308
Investment in brand value (million Euro)	5,414	2.709	32.250	0	1380.117
Investment in software & databases (million Euro)	5,414	1.239	14.063	0	622.2153

Table A4. Summary statistics of model variables, goods, services and sub-sectors – Top 20% S&D firms

Total

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	13,320	407.103	2127.055	0.2480	77068.92
Intermediary input (million Euro)	13,320	255.834	1476.055	0.007466	64405.16
Labour (head count)	13,320	1130.918	5590.146	1	183991
Tangible capital stock (million Euro)	13,320	254.103	1798.447	0.001690	58855.33
Investment in research & development (million Euro)	13,320	69.023	686.083	0	29881.95
Investment in firm specific human capital (million Euro)	13,320	4.516	28.579	0	973.401
Investment in brand value (million Euro)	13,320	40.944	484.715	0	22268.74
Investment in software & databases (million Euro)	13,320	15.618	203.354	0.3696641	10355.07

Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	4,506	449.846	2015.522	0.2480	39183.37
Intermediary input (million Euro)	4,506	272.320	1215.238	0.007466	22054.4
Labour (head count)	4,506	1344.056	8083.446	1	183991
Tangible capital stock (million Euro)	4,506	251.599	2468.328	0.001690	58855.33
Investment in research & development (million Euro)	4,506	22.964	314.723	0	10771.05
Investment in firm specific human capital (million Euro)	4,506	5.726	34.605	0	599.1818
Investment in brand value (million Euro)	4,506	39.023	339.000	0	9779.824
Investment in software & databases (million Euro)	4,506	29.633	341.522	0.3696641	10355.07

Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	8,814	385.251	2181.661	0.3113	77068.92
Intermediary input (million Euro)	8,814	247.406	1592.981	0.009531	64405.16
Labour (head count)	8,814	1021.955	3713.617	4	94924.4
Tangible capital stock (million Euro)	8,814	255.384	1331.809	0.009292	37468.55
Investment in research & development (million Euro)	8,814	92.570	811.855	0	29881.95
Investment in firm specific human capital (million Euro)	8,814	3.897	24.922	0	973.401
Investment in brand value (million Euro)	8,814	41.927	544.360	0	22268.74
Investment in software & databases (million Euro)	8,814	8.453	52.177	0.36977	1709.513

Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	7,250	392.207	2361.172	0.3113002	77068.92
Intermediary input (million Euro)	7,250	249.399	1721.117	0.05000	64405.16
Labour (head count)	7,250	1089.810	3973.132	4	94924.4
Tangible capital stock (million Euro)	7,250	204.332	1294.221	0.009292	37468.55
Investment in research & development (million Euro)	7,250	111.066	893.282	0	29881.95
Investment in firm specific human capital (million Euro)	7,250	4.243	27.292	0	973.401
Investment in brand value (million Euro)	7,250	49.290	599.853	0	22268.74
Investment in software & databases (million Euro)	7,250	8.772	55.747	0.36977	1709.513

High Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,748	566.223	3223.350	0.5290	77068.92
Intermediary input (million Euro)	3,748	363.248	2350.837	0.09665	64405.16
Labour (head count)	3,748	1435.577	5230.904	7	94924.4
Tangible capital stock (million Euro)	3,748	299.796	1748.147	0.009292	37468.55
Investment in research & development (million Euro)	3,748	197.342	1231.057	0	29881.95
Investment in firm specific human capital (million Euro)	3,748	6.304	35.351	0	973.401
Investment in brand value (million Euro)	3,748	81.847	831.521	0	22268.74
Investment in software & databases (million Euro)	3,748	13.854	76.371	0.3701029	1709.513

Medium Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	2,178	241.468	726.676	0.3113002	10271.69
Intermediary input (million Euro)	2,178	152.434	530.315	0.07792	9654.632
Labour (head count)	2,178	803.271	2029.774	6	22136.33
Tangible capital stock (million Euro)	2,178	129.108	520.623	0.013490	7238.764
Investment in research & development (million Euro)	2,178	26.835	147.021	0	3090.02
Investment in firm specific human capital (million Euro)	2,178	2.853	17.634	0	399.5009
Investment in brand value (million Euro)	2,178	13.910	54.905	0	593.3551
Investment in software & databases (million Euro)	2,178	3.873	14.042	0.3702697	206.2401

Low Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,324	147.571	262.371	0.5812	2798.916
Intermediary input (million Euro)	1,324	86.618	193.187	0.05000	2540.726
Labour (head count)	1,324	582.370	1219.424	4	11814
Tangible capital stock (million Euro)	1,324	57.833	140.934	0.018584	1572.525
Investment in research & development (million Euro)	1,324	5.398	20.915	0	269.5357
Investment in firm specific human capital (million Euro)	1,324	0.699	1.581	0	22.65845
Investment in brand value (million Euro)	1,324	15.330	45.937	0	524.7737
Investment in software & databases (million Euro)	1,324	2.446	5.605	0.36977	66.06615

Other Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,564	353.004	989.593	0.5921	10189.95
Intermediary input (million Euro)	1,564	238.170	754.724	0.0095311	8184.329
Labour (head count)	1,564	707.409	2104.202	5	25492
Tangible capital stock (million Euro)	1,564	492.037	1471.227	0.038257	15899.36
Investment in research & development (million Euro)	1,564	6.832	81.519	0	2207.876
Investment in firm specific human capital (million Euro)	1,564	2.292	6.662	0	84.5862
Investment in brand value (million Euro)	1,564	7.793	24.800	0	310.4839
Investment in software & databases (million Euro)	1,564	6.971	30.573	0.3703321	674.6097

Trade

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	640	578.543	1456.494	0.3601	7682.654
Intermediary input (million Euro)	640	464.282	1237.681	0.05000	7316.279
Labour (head count)	640	935.683	3366.129	7	26113
Tangible capital stock (million Euro)	640	90.584	430.269	0.002669	4096.088
Investment in research & development (million Euro)	640	1.813	7.920	0	77.81317
Investment in firm specific human capital (million Euro)	640	1.196	5.337	0	92.69587
Investment in brand value (million Euro)	640	37.165	323.793	0	5944.139
Investment in software & databases (million Euro)	640	6.194	17.372	0.3704052	116.5779

Transportation

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	690	596.568	2313.887	1.2505	20779.27
Intermediary input (million Euro)	690	332.135	1403.687	0.095743	14939.55
Labour (head count)	690	3626.117	18137.150	6	183991
Tangible capital stock (million Euro)	690	973.263	4854.160	0.00888	58855.33
Investment in research & development (million Euro)	690	7.187	32.266	0	344.1723
Investment in firm specific human capital (million Euro)	690	9.805	48.076	0	451.4766
Investment in brand value (million Euro)	690	42.071	221.866	0	1996.97
Investment in software & databases (million Euro)	690	13.884	50.499	0.3720336	428.691

ICT services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,016	343.045	2027.326	0.2546	28933.42
Intermediary input (million Euro)	1,016	147.301	833.525	0.027633	14732.12
Labour (head count)	1,016	1003.347	6332.557	1	102809
Tangible capital stock (million Euro)	1,016	280.679	3225.604	0.002534	54063.54
Investment in research & development (million Euro)	1,016	78.420	654.512	0	10771.05
Investment in firm specific human capital (million Euro)	1,016	6.939	44.151	0	534.9573
Investment in brand value (million Euro)	1,016	69.264	614.073	0	9779.824
Investment in software & databases (million Euro)	1,016	83.533	703.956	0.3700347	10355.07

Professional Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	860	63.158	240.070	0.2480	2156.66
Intermediary input (million Euro)	860	16.564	68.457	0.007466	760.6048
Labour (head count)	860	491.124	1788.260	3	16810
Tangible capital stock (million Euro)	860	15.429	65.730	0.001690	589.4814
Investment in research & development (million Euro)	860	2.207	9.937	0	164.5553
Investment in firm specific human capital (million Euro)	860	4.491	38.271	0	599.1818
Investment in brand value (million Euro)	860	3.632	19.633	0	270.0637
Investment in software & databases (million Euro)	860	2.356	7.304	0.3696641	75.56844

Other Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	1,300	647.889	2605.502	0.4721	39183.37
Intermediary input (million Euro)	1,300	412.967	1637.576	0.008895	22054.4
Labour (head count)	1,300	1164.377	3106.947	2	36742
Tangible capital stock (million Euro)	1,300	81.340	227.908	0.010856	2983.029
Investment in research & development (million Euro)	1,300	12.140	70.545	0	1218.915
Investment in firm specific human capital (million Euro)	1,300	5.661	20.009	0	290.737
Investment in brand value (million Euro)	1,300	38.098	156.263	0	2126.281
Investment in software & databases (million Euro)	1,300	25.451	112.119	0.3729979	2377.917

Table A5. Summary statistics of model variables, goods, services and sub-sectors – Lower 80% S&D firms

Total

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	53,279	9.863	43.441	0.0143	2228.307
Intermediary input (million Euro)	53,279	5.147	29.897	0.000513	2041.032
Labour (head count)	53,279	56.050	157.006	1	6139
Tangible capital stock (million Euro)	53,279	3.621	25.623	0.000153	1600.937
Investment in research & development (million Euro)	53,279	0.583	5.251	0	389.8648
Investment in firm specific human capital (million Euro)	53,279	0.085	0.654	0	59.47146
Investment in brand value (million Euro)	53,279	0.655	14.829	0	1577.541
Investment in software & databases (million Euro)	53,279	0.065	0.083	0	0.3696387

Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	22,149	6.241	30.325	0.0143	1604.543
Intermediary input (million Euro)	22,149	2.863	17.748	0.000552	1073.883
Labour (head count)	22,149	50.576	192.514	1	6139
Tangible capital stock (million Euro)	22,149	2.321	30.831	0.000153	1600.937
Investment in research & development (million Euro)	22,149	0.215	3.894	0	291.8922
Investment in firm specific human capital (million Euro)	22,149	0.075	0.445	0	17.92214
Investment in brand value (million Euro)	22,149	0.412	6.860	0	597.0971
Investment in software & databases (million Euro)	22,149	0.060	0.079	0	0.3696211

Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	31,130	12.439	50.592	0.0149	2228.307
Intermediary input (million Euro)	31,130	6.772	36.046	0.000513	2041.032
Labour (head count)	31,130	59.944	125.639	1	4319
Tangible capital stock (million Euro)	31,130	4.546	21.102	0.000296	767.844
Investment in research & development (million Euro)	31,130	0.844	6.020	0	389.8648
Investment in firm specific human capital (million Euro)	31,130	0.092	0.769	0	59.47146
Investment in brand value (million Euro)	31,130	0.828	18.515	0	1577.541
Investment in software & databases (million Euro)	31,130	0.068	0.086	0	0.3696387

Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	25,182	13.006	55.153	0.023	2228.307
Intermediary input (million Euro)	25,182	7.186	39.395	0.00102	2041.032
Labour (head count)	25,182	62.939	131.355	1	4319
Tangible capital stock (million Euro)	25,182	3.245	16.110	0.000296	576.4357
Investment in research & development (million Euro)	25,182	1.028	6.678	0	389.8648
Investment in firm specific human capital (million Euro)	25,182	0.097	0.834	0	59.47146
Investment in brand value (million Euro)	25,182	0.983	20.578	0	1577.541
Investment in software & databases (million Euro)	25,182	0.071	0.087	0	0.3696387

High Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	8,105	16.070	64.062	0.0285	2228.307
Intermediary input (million Euro)	8,105	9.018	47.316	0.00407	2041.032
Labour (head count)	8,105	67.855	134.404	1	2442
Tangible capital stock (million Euro)	8,105	3.492	12.941	0.000634	236.7997
Investment in research & development (million Euro)	8,105	2.126	8.062	0	227.0719
Investment in firm specific human capital (million Euro)	8,105	0.123	0.872	0	29.77234
Investment in brand value (million Euro)	8,105	0.627	2.615	0	58.89359
Investment in software & databases (million Euro)	8,105	0.086	0.092	0	0.3696387

Medium Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	9,945	10.793	40.350	0.023	1737.055
Intermediary input (million Euro)	9,945	5.496	25.115	0.00106	1507.731
Labour (head count)	9,945	60.222	123.461	1	2600
Tangible capital stock (million Euro)	9,945	3.143	17.287	0.000296	576.4357
Investment in research & development (million Euro)	9,945	0.653	7.341	0	389.8648
Investment in firm specific human capital (million Euro)	9,945	0.101	1.019	0	59.47146
Investment in brand value (million Euro)	9,945	1.332	31.446	0	1577.541
Investment in software & databases (million Euro)	9,945	0.069	0.085	0	0.3695676

Low Tech Manufacturing

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	7,132	12.610	61.557	0.0267	2032.583
Intermediary input (million Euro)	7,132	7.461	45.260	0.00102	1620.185
Labour (head count)	7,132	61.140	138.210	1	4319
Tangible capital stock (million Euro)	7,132	3.108	17.588	0.000845	502.6182
Investment in research & development (million Euro)	7,132	0.302	2.525	0	93.03349
Investment in firm specific human capital (million Euro)	7,132	0.061	0.381	0	17.7737
Investment in brand value (million Euro)	7,132	0.899	10.408	0	526.4985
Investment in software & databases (million Euro)	7,132	0.056	0.080	0	0.3688522

Other Goods

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	5,948	10.040	22.606	0.0149	332.9693
Intermediary input (million Euro)	5,948	5.022	15.038	0.000513	269.9124
Labour (head count)	5,948	47.263	96.791	1	1867
Tangible capital stock (million Euro)	5,948	10.050	34.560	0.000859	767.844
Investment in research & development (million Euro)	5,948	0.068	0.357	0	8.541698
Investment in firm specific human capital (million Euro)	5,948	0.072	0.384	0	16.65261
Investment in brand value (million Euro)	5,948	0.173	0.875	0	22.17007
Investment in software & databases (million Euro)	5,948	0.055	0.079	0	0.368846

Trade

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	2,753	13.906	34.182	0.0158	660.6518
Intermediary input (million Euro)	2,753	9.722	28.833	0.00423	632.9737
Labour (head count)	2,753	40.220	72.700	1	1000
Tangible capital stock (million Euro)	2,753	1.504	4.574	0.000845	100.5288
Investment in research & development (million Euro)	2,753	0.045	0.157	0	2.078392
Investment in firm specific human capital (million Euro)	2,753	0.075	0.608	0	16.12224
Investment in brand value (million Euro)	2,753	0.354	1.189	0	27.96996
Investment in software & databases (million Euro)	2,753	0.061	0.077	0	0.3694946

Transportation

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,291	11.029	61.321	0.0498	1604.543
Intermediary input (million Euro)	3,291	4.436	19.382	0.000987	353.0938
Labour (head count)	3,291	81.292	323.451	1	6139
Tangible capital stock (million Euro)	3,291	9.452	77.526	0.00102	1600.937
Investment in research & development (million Euro)	3,291	0.479	9.781	0	291.8922
Investment in firm specific human capital (million Euro)	3,291	0.097	0.758	0	17.92214
Investment in brand value (million Euro)	3,291	0.742	8.500	0	242.868
Investment in software & databases (million Euro)	3,291	0.042	0.073	0	0.3692243

ICT services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	3,425	4.964	22.196	0.0229	495.0275
Intermediary input (million Euro)	3,425	1.824	10.641	0.000858	228.6447
Labour (head count)	3,425	36.008	95.074	1	1889
Tangible capital stock (million Euro)	3,425	0.920	6.689	0.000845	162.2691
Investment in research & development (million Euro)	3,425	0.563	2.327	0	89.64603
Investment in firm specific human capital (million Euro)	3,425	0.087	0.444	0	11.29958
Investment in brand value (million Euro)	3,425	0.628	6.817	0	228.4588
Investment in software & databases (million Euro)	3,425	0.071	0.086	0	0.3693479

Professional Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	8,140	2.001	4.527	0.0143	157.8608
Intermediary input (million Euro)	8,140	0.578	3.008	0.000552	91.54637
Labour (head count)	8,140	20.879	31.389	1	785
Tangible capital stock (million Euro)	8,140	0.286	0.964	0.000153	22.41975
Investment in research & development (million Euro)	8,140	0.113	0.405	0	6.657464
Investment in firm specific human capital (million Euro)	8,140	0.051	0.126	0	2.322377
Investment in brand value (million Euro)	8,140	0.085	0.299	0	12.97576
Investment in software & databases (million Euro)	8,140	0.069	0.079	0	0.3695167

Other Services

Variable	Obs	Mean	Std. Dev.	Min	Max
Gross output (million Euro)	4,540	6.690	23.644	0.0296	930.6965
Intermediary input (million Euro)	4,540	2.443	24.866	0.000818	1073.883
Labour (head count)	4,540	98.826	297.322	1	6000
Tangible capital stock (million Euro)	4,540	2.351	13.689	0.000253	404.1035
Investment in research & development (million Euro)	4,540	0.046	0.207	0	3.377432
Investment in firm specific human capital (million Euro)	4,540	0.091	0.384	0	10.37672
Investment in brand value (million Euro)	4,540	0.631	11.868	0	597.0971
Investment in software & databases (million Euro)	4,540	0.051	0.075	0	0.3696211

Appendix B. Additional Econometric Results

Table B1. Intangible Capital and Firm-Level Productivity – LP estimation only with R&D – based on Table 2

	(1) ME 2011-2022	(2) ME 2011-2015	(3) ME 2016-2019	(4) ME 2020-2022	(5) ME 2020-2022	(6) Services 2011-2022	(7) Services 2011-2015	(8) Services 2016-2019	(9) Services 2020-2022	(10) Services 2020-2022	(11) Goods 2011-2022	(12) Goods 2011-2015	(13) Goods 2016-2019	(14) Goods 2020-2022	(15) Goods 2020-2022
Labour	0.517***	0.516***	0.519***	0.518***	0.525***	0.587***	0.591***	0.585***	0.587***	0.591***	0.416***	0.415***	0.419***	0.412***	0.424***
	(50.32)	(57.50)	(41.25)	(41.63)	(39.44)	(38.75)	(34.84)	(31.77)	(27.11)	(24.48)	(40.00)	(30.33)	(31.15)	(26.41)	(25.47)
Materials	0.430***	0.399***	0.421***	0.305***	0.403***	0.229***	0.345***	0.208***	0.334***	0.212***	0.508***	0.466***	0.511***	0.513***	0.488***
	(149.50)	(12.44)	(335.48)	(5.20)	(6.85)	(6.46)	(27.03)	(5.99)	(5.44)	(5.47)	(19.71)	(22.19)	(9.11)	(14.41)	(7.70)
Tangible Capital	0.0827***	0.0558***	0.0807***	0.00134	0.0641***	0.0364**	0.0875***	0.0752***	0.0816***	0.0948***	0.0580***	-0.00101	0.0547***	0.0642***	0.0516*
	(34.72)	(6.84)	(41.05)	(0.04)	(2.72)	(2.31)	(28.87)	(4.18)	(2.67)	(4.38)	(5.45)	(-0.17)	(3.64)	(3.42)	(1.92)
Research & Development	0.00608***	0.00617***	0.00608***	0.00585***	0.00658***	0.00992***	0.0119***	0.00837***	0.00836***	0.00974***	0.00401***	0.00340***	0.00476***	0.00409**	0.00429***
	(5.87)	(4.90)	(4.55)	(4.55)	(4.06)	(4.65)	(4.33)	(3.23)	(2.70)	(3.07)	(3.55)	(2.71)	(3.53)	(2.32)	(2.86)
Covid					0.0623***					0.0769***					0.0369**
					(3.78)					(2.82)					(2.15)
N	66599	28789	23062	14748	13731	26655	11253	9335	6067	5658	39944	17536	13727	8681	8073

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B2. Intangible Capital and Firm-Level Productivity - LP estimation only with R&D – based on Table 3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Goods Total	Manufacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.416***	0.412***	0.433***	0.423***	0.401***	0.418***	0.587***	0.494***	0.462***	0.726***	0.713***	0.529***
	(37.80)	(33.49)	(20.99)	(21.15)	(15.67)	(15.13)	(40.18)	(8.98)	(11.76)	(23.72)	(33.52)	(17.86)
Materials	0.488***	0.512***	0.493***	0.411***	0.524***	0.477***	0.228***	0.480***	0.343***	0.293***	0.154***	0.318***
	(129.32)	(28.19)	(59.99)	(9.74)	(190.15)	(27.02)	(6.27)	(12.31)	(8.62)	(11.13)	(9.01)	(17.55)
Tangible Capital	0.0332***	0.0448***	0.0182**	0.0515***	0.0537***	0.0777***	0.0673***	0.0957***	0.0466**	0.0320***	0.0553***	0.0869***
	(6.06)	(6.42)	(2.38)	(3.41)	(26.40)	(7.52)	(2.99)	(7.69)	(2.27)	(3.14)	(5.63)	(6.45)
Research & Development	0.00401***	0.00543***	0.00736***	0.00331*	0.00419*	-0.00546*	0.00992***	-0.000177	0.0202***	0.00610	0.000314	0.0264***
	(3.46)	(4.61)	(3.54)	(1.94)	(1.94)	(-1.91)	(4.65)	(-0.03)	(3.54)	(1.17)	(0.10)	(4.84)
N	39944	32432	11853	12123	8456	7512	26655	3393	3981	4441	9000	5840

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B3. Intangible Capital and Firm-Level Productivity – LP estimation - Goods Sectors over time – based on Table 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	2011-2022	2011-2022	2011-2022	2011-2022	2011-2022	2011-2022	2011-2015	2011-2015	2011-2015	2011-2015	2011-2015	2011-2015
	Goods Total	Maunfacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Goods Total	Maunfacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods
Labour	0.399***	0.395***	0.410***	0.411***	0.388***	0.402***	0.400***	0.400***	0.405***	0.426***	0.392***	0.395***
	(39.38)	(34.77)	(22.35)	(19.68)	(16.97)	(14.98)	(31.98)	(31.37)	(17.78)	(20.21)	(13.68)	(12.17)
Materials	0.514***	0.501***	0.437***	0.502***	0.521***	0.453***	0.503***	0.511***	0.504***	0.470***	0.519***	0.454***
	(204.41)	(66.03)	(10.16)	(24.52)	(12.23)	(67.03)	(114.63)	(12.55)	(30.25)	(26.97)	(9.34)	(9.44)
Tangibel Capital	0.0686***	0.0354***	0.0220	0.0479***	0.0576***	0.0515***	0.0570***	0.0487***	0.0255***	0.0323***	0.0647***	0.0506***
	(30.04)	(11.92)	(1.60)	(8.87)	(4.60)	(11.73)	(27.70)	(4.82)	(3.27)	(3.14)	(5.57)	(3.54)
Research & Development	0.000370	0.00137	0.00301	0.000756	0.0000784	-0.00675**	-0.000147	0.00109	0.00173	0.00199	-0.000145	-0.00955**
	(0.35)	(1.17)	(1.34)	(0.52)	(0.03)	(-1.96)	(-0.13)	(0.79)	(0.65)	(0.99)	(-0.05)	(-2.46)
Software & Databases	0.00758***	0.00874***	0.00795**	0.00659**	0.0132***	0.00576	0.00615***	0.00819***	0.00581	0.00702*	0.0140***	0.00133
	(3.40)	(3.45)	(2.24)	(2.05)	(3.20)	(0.98)	(2.74)	(3.19)	(1.55)	(1.92)	(2.91)	(0.19)
Firm-Specific Human Capital	0.0171***	0.0181***	0.0199***	0.0135***	0.0150***	0.0113*	0.0182***	0.0185***	0.0203***	0.0134***	0.0163***	0.0146*
	(7.43)	(7.47)	(4.68)	(4.01)	(3.68)	(1.72)	(6.39)	(6.97)	(4.55)	(3.01)	(3.01)	(1.65)
Brand Value	0.00468***	0.00338*	0.00389	0.00148	0.00137	0.00636	0.00410**	0.00250	0.00396	-0.00170	0.00222	0.00709
	(2.65)	(1.84)	(1.51)	(0.47)	(0.39)	(1.36)	(1.99)	(1.28)	(1.48)	(-0.44)	(0.56)	(1.35)
N	39,944	32,432	11,853	12,123	8,456	7,512	17,536	14,318	5,319	5,147	3,852	3,218
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	2016-2019	2016-2019	2016-2019	2016-2019	2016-2019	2016-2019	2020-2022	2020-2022	2020-2022	2020-2022	2020-2022	2020-2022
	Goods Total	Maunfacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Goods Total	Maunfacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods
Labour	0.400***	0.396***	0.425***	0.402***	0.377***	0.410***	0.395***	0.384***	0.393***	0.394***	0.397***	0.422***
	(31.17)	(26.12)	(16.57)	(21.11)	(12.12)	(10.36)	(21.97)	(20.08)	(15.33)	(11.59)	(12.18)	(10.69)
Materials	0.495***	0.519***	0.505***	0.491***	0.530***	0.459***	0.518***	0.418***	0.512***	0.352***	0.498***	0.291***
	(16.49)	(14.73)	(7.91)	(9.44)	(53.54)	(11.65)	(92.82)	(5.73)	(7.73)	(8.20)	(6.09)	(4.27)
Tangibel Capital	0.0416***	0.0489***	0.0438***	0.0388***	0.0383***	0.0404**	0.0750***	0.0957***	0.0421	-0.0304**	0.0584**	0.0656*
	(5.35)	(5.05)	(5.60)	(4.41)	(9.49)	(2.25)	(21.42)	(3.81)	(1.33)	(-2.46)	(2.00)	(1.82)
Research & Development	0.000850	0.00141	0.00402	0.000239	-0.000747	-0.00508	0.000601	0.00198	0.00482	-0.000502	0.00174	-0.00599
	(0.56)	(0.88)	(1.24)	(0.13)	(-0.25)	(-1.13)	(0.39)	(1.08)	(1.58)	(-0.19)	(0.50)	(-1.17)
Software & Databases	0.0118***	0.0126***	0.0167***	0.00515	0.0178***	0.0109*	0.00364	0.00391	0.00133	0.00892	0.00179	0.00316
	(4.69)	(4.63)	(3.42)	(1.24)	(3.18)	(1.70)	(1.12)	(1.11)	(0.26)	(1.39)	(0.26)	(0.44)
Firm-Specific Human Capital	0.0168***	0.0186***	0.0229***	0.0140***	0.0130***	0.00690	0.0156***	0.0163***	0.0152**	0.0116**	0.0161**	0.0133
	(6.16)	(5.50)	(3.25)	(3.88)	(2.63)	(0.75)	(4.55)	(4.01)	(2.51)	(2.12)	(2.12)	(1.62)
Brand Value	0.00429*	0.00457**	0.00481	0.00439	-0.000103	0.00127	0.00693***	0.00384	0.00411	0.00282	0.00176	0.0148***
	(1.94)	(2.32)	(1.24)	(1.37)	(-0.02)	(0.20)	(2.66)	(1.23)	(0.91)	(0.66)	(0.37)	(2.94)
N	13,727	11,104	3,986	4,299	2,819	2,623	8,681	7,010	2,548	2,677	1,785	1,671

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B4. Intangible Capital and Firm-Level Productivity – LP estimation - Services Sectors over time – based on Table 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	2011-2022	2011-2022	2011-2022	2011-2022	2011-2022	2011-2022	2011-2015	2011-2015	2011-2015	2011-2015	2011-2015	2011-2015
	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.551***	0.486***	0.438***	0.674***	0.676***	0.488***	0.558***	0.503***	0.403***	0.683***	0.652***	0.514***
	(35.46)	(9.61)	(10.94)	(19.20)	(33.45)	(16.62)	(31.63)	(7.51)	(8.34)	(13.25)	(24.02)	(15.80)
Materials	0.341***	0.434***	0.347***	0.276***	0.213***	0.325***	0.338***	0.291***	0.191**	0.266***	0.151***	0.239***
	(22.22)	(10.46)	(7.06)	(13.43)	(11.35)	(65.42)	(10.88)	(3.01)	(2.40)	(7.51)	(4.90)	(5.42)
Tangibel Capital	0.0828***	0.0544***	0.0557***	0.0160**	0.0406***	0.0880***	0.0690***	0.0407	0.0501*	0.0128	0.0512***	0.0536***
	(26.91)	(3.17)	(4.10)	(2.06)	(5.43)	(39.74)	(9.18)	(0.99)	(1.65)	(0.84)	(3.10)	(3.33)
Research & Development	0.00348	-0.00175	0.0164***	-0.00265	-0.00369	0.0161***	0.00494*	0.00999	0.0152**	-0.00358	-0.00336	0.0165**
	(1.54)	(-0.29)	(2.62)	(-0.55)	(-1.21)	(2.68)	(1.83)	(1.27)	(2.12)	(-0.56)	(-0.92)	(2.45)
Software & Databases	0.0303***	0.0227*	0.0270***	0.0216***	0.0263***	0.0388***	0.0306***	0.0186	0.0315***	0.0116	0.0306***	0.0427***
	(6.74)	(1.91)	(3.02)	(2.67)	(3.92)	(4.90)	(6.77)	(1.41)	(2.76)	(0.97)	(3.99)	(4.86)
Firm-Specific Human Capital	0.0208***	-0.0205**	0.0314**	0.0297***	0.0217***	0.0300***	0.0194***	-0.0278*	0.0396***	0.0339***	0.0150*	0.0318**
	(4.24)	(-2.04)	(2.34)	(3.59)	(3.30)	(3.03)	(3.54)	(-1.69)	(2.69)	(2.89)	(1.73)	(2.24)
Brand Value	0.00917***	0.0110	-0.0123*	0.0161**	0.00356	0.0137*	0.0118***	0.0154	-0.0140*	0.0145	0.00591	0.0208*
	(2.79)	(1.03)	(-1.71)	(2.09)	(0.67)	(1.74)	(3.08)	(1.29)	(-1.69)	(1.49)	(0.99)	(1.95)
N	26,655	3,393	3,981	4,441	9,000	5,840	11,253	1,359	1,719	1,976	3,765	2,434
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	2016-2019	2016-2019	2016-2019	2016-2019	2016-2019	2016-2019	2020-2022	2020-2022	2020-2022	2020-2022	2020-2022	2020-2022
	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.542***	0.510***	0.448***	0.664***	0.675***	0.464***	0.555***	0.444***	0.527***	0.694***	0.721***	0.465***
	(26.95)	(6.53)	(7.06)	(15.54)	(22.31)	(11.86)	(23.07)	(6.40)	(9.41)	(11.98)	(19.14)	(10.42)
Materials	0.229***	0.301***	0.319***	0.208***	0.231***	0.329***	0.355***	0.488***	0.348***	0.193***	0.222***	0.346***
	(7.85)	(4.88)	(11.71)	(5.66)	(17.62)	(6.38)	(24.85)	(4.79)	(4.79)	(2.69)	(6.27)	(13.86)
Tangibel Capital	0.0681***	0.0653**	0.0558***	0.0285	0.0480***	0.0893***	0.125***	0.100***	0.0585*	0.0356	0.0440*	0.0974***
	(3.76)	(2.33)	(4.78)	(1.32)	(22.50)	(3.98)	(22.66)	(6.24)	(1.70)	(0.71)	(1.86)	(3.64)
Research & Development	0.00162	-0.0109	0.0239**	-0.00275	-0.00420	0.0136	0.00342	-0.00322	0.00866	-0.00131	-0.00347	0.0172**
	(0.63)	(-1.60)	(2.36)	(-0.54)	(-1.10)	(1.44)	(1.14)	(-0.42)	(1.16)	(-0.19)	(-0.81)	(2.53)
Software & Databases	0.0324***	0.0229	0.0205	0.0248**	0.0259***	0.0521***	0.0266***	0.0270*	0.0233**	0.0456***	0.0194*	0.0154
	(5.89)	(1.34)	(1.17)	(2.19)	(2.98)	(5.23)	(4.85)	(1.94)	(2.11)	(3.15)	(1.91)	(1.04)
Firm-Specific Human Capital	0.0236***	-0.0167	0.0371*	0.0265**	0.0275***	0.0271**	0.0186***	-0.0208*	0.00644	0.0235*	0.0255**	0.0259
	(3.61)	(-1.11)	(1.84)	(2.47)	(3.30)	(2.03)	(2.83)	(-1.82)	(0.43)	(1.68)	(2.30)	(1.59)
Brand Value	0.0111**	0.00619	-0.00885	0.0227**	0.00484	0.0121	0.00132	0.00887	-0.0174**	0.00651	-0.00100	0.00678
	(2.47)	(0.44)	(-0.95)	(2.37)	(0.80)	(1.04)	(0.31)	(0.74)	(-2.05)	(0.43)	(-0.14)	(0.68)
N	9,335	1,154	1,407	1,537	3,205	2,032	6,067	880	855	928	2,030	1,374

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B5. Intangible Capital and Firm-Level Productivity - Woolridge System GMM estimation – based on Table 4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	ME	ME	ME	ME	ME	Services	Services	Services	Services	Services	Goods	Goods	Goods	Goods	Goods
	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022
Labour	0.495***	0.500***	0.491***	0.507***	0.515***	0.562***	0.578***	0.542***	0.565***	0.573***	0.400***	0.400***	0.402***	0.414***	0.424***
	(149.88)	(92.51)	(78.82)	(62.29)	(63.21)	(97.09)	(59.95)	(50.25)	(40.64)	(41.56)	(105.80)	(65.54)	(55.96)	(43.27)	(43.59)
Materials	-0.219***	-0.160***	0.00293	-0.318***	-0.323***	-0.586***	-0.633***	-0.281***	-0.327***	-0.333***	-0.170***	-0.123***	-0.0563**	-0.142***	-0.153***
	(-26.73)	(-13.57)	(0.58)	(-11.05)	(-11.22)	(-26.32)	(-16.91)	(-6.85)	(-6.51)	(-6.68)	(-24.25)	(-5.96)	(-2.30)	(-4.52)	(-4.80)
Tangibel Capital	0.0332***	0.0310***	0.0343***	0.0369***	0.0353***	0.0414***	0.0355***	0.0471***	0.0552***	0.0566***	0.0235***	0.0234***	0.0263***	0.0232**	0.0199**
	(9.99)	(6.19)	(5.89)	(4.35)	(4.19)	(6.73)	(3.64)	(4.56)	(3.56)	(3.70)	(6.62)	(4.49)	(4.14)	(2.50)	(2.15)
Research & Development	0.00142***	0.00150**	0.000215	0.00222**	0.00269***	0.00402***	0.00676***	0.000460	0.00469**	0.00573***	0.000554	-0.000380	0.000768	-0.000314	-0.000317
	(3.32)	(2.11)	(0.27)	(2.17)	(2.62)	(4.86)	(4.79)	(0.30)	(2.39)	(2.93)	(1.25)	(-0.52)	(0.90)	(-0.29)	(-0.29)
Software & Databases	0.0166***	0.0154***	0.0203***	0.0114***	0.0111***	0.0306***	0.0282***	0.0336***	0.0247***	0.0229***	0.00557***	0.00458***	0.00992***	0.00230	0.00303
	(22.21)	(12.69)	(14.25)	(6.18)	(6.00)	(21.22)	(11.96)	(12.35)	(7.07)	(6.57)	(7.16)	(3.63)	(6.68)	(1.18)	(1.53)
Firm-Specific Human Capital	0.0198***	0.0209***	0.0220***	0.0149***	0.0141***	0.0191***	0.0185***	0.0229***	0.0133***	0.00897**	0.0177***	0.0199***	0.0181***	0.0153***	0.0160***
	(23.37)	(14.61)	(13.73)	(7.59)	(7.16)	(11.88)	(6.76)	(7.69)	(3.54)	(2.40)	(19.87)	(13.17)	(10.61)	(7.39)	(7.68)
Brand Value	0.00558***	0.00574***	0.00651***	0.00225	0.00327**	0.00779***	0.0100***	0.0112***	-0.00106	0.00282	0.00481***	0.00366***	0.00383***	0.00505***	0.00443***
	(9.70)	(6.07)	(5.98)	(1.60)	(2.33)	(6.65)	(5.01)	(5.18)	(-0.39)	(1.04)	(8.24)	(3.86)	(3.42)	(3.45)	(2.99)
Covid					0.00400					0.000556					0.00661
					(0.62)					(0.05)					(0.95)
N	50,492	18,973	13,934	8,183	7,946	19,821	7,229	5,555	3,319	3,222	30,266	11,549	8,285	4,800	4,663

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B6. Intangible Capital and Firm-Level Productivity - Woolridge System GMM estimation – based on Table 5

	(1) Goods Total	(2) Manufacturing Total	(3) High-Tech	(4) Medium-Tech	(5) Low-Tech	(6) Other Goods	(7) Services Total	(8) Wholesale & Retail Trade	(9) Transportation & Storage	(10) IC	(11) Professional Services	(12) Other Services
Labour	0.400***	0.400***	0.419***	0.412***	0.393***	0.380***	0.562***	0.510***	0.417***	0.701***	0.702***	0.484***
	(105.80)	(95.10)	(55.76)	(61.60)	(48.01)	(40.22)	(97.09)	(24.85)	(26.69)	(49.12)	(83.16)	(37.25)
Materials	-0.170***	-0.0594***	0.0171*	0.0551***	-0.274***	-0.146***	-0.586***	0.00267	-0.000151	0.00136	0.00610	0.470***
	(-24.25)	(-8.66)	(1.93)	(5.77)	(-9.76)	(-4.38)	(-26.32)	(0.18)	(-0.01)	(0.12)	(0.74)	(26.83)
Tangibel Capital	0.0235***	0.0182***	0.0136*	0.0110	0.0291***	0.0367***	0.0414***	0.0337	0.0108	0.0177	0.0300***	0.0684***
	(6.62)	(4.13)	(1.88)	(1.57)	(3.16)	(5.68)	(6.73)	(1.64)	(0.73)	(1.25)	(3.51)	(4.78)
Research & Development	0.000554	0.00153***	0.00366***	0.00110	-0.000811	-0.00720***	0.00402***	-0.00267	0.0172***	-0.000498	-0.00389***	0.0186***
	(1.25)	(3.24)	(4.16)	(1.55)	(-0.82)	(-5.57)	(4.86)	(-1.04)	(6.97)	(-0.30)	(-3.26)	(8.69)
Software & Databases	0.00557***	0.00718***	0.00689***	0.00325**	0.0128***	0.00440**	0.0306***	0.0207***	0.0261***	0.0236***	0.0238***	0.0414***
	(7.16)	(8.43)	(4.53)	(2.50)	(7.50)	(2.30)	(21.22)	(4.74)	(8.47)	(7.24)	(9.46)	(12.74)
Firm-Specific Human Capital	0.0177***	0.0187***	0.0216***	0.0118***	0.0166***	0.0139***	0.0191***	-0.0208***	0.0412***	0.0247***	0.0216***	0.0223***
	(19.87)	(20.18)	(11.90)	(8.29)	(9.61)	(5.24)	(11.88)	(-4.65)	(10.07)	(7.53)	(8.31)	(5.76)
Brand Value	0.00481***	0.00377***	0.00391***	0.00339***	0.000454	0.00472***	0.00779***	0.00737*	-0.0135***	0.0110***	0.00194	0.0140***
	(8.24)	(5.91)	(3.58)	(3.43)	(0.34)	(3.25)	(6.65)	(1.80)	(-5.59)	(4.01)	(1.10)	(4.69)
N	30,266	24,499	8,714	8,884	6,330	5,636	19,821	2,467	2,959	3,204	6,797	4,103

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B7. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% R&D firms, Extended Model Specification.

	(1) ME 2011-2022	(2) ME 2011-2015	(3) ME 2016-2019	(4) ME 2020-2022	(5) ME 2020-2022	(6) Services 2011-2022	(7) Services 2011-2015	(8) Services 2016-2019	(9) Services 2020-2022	(10) Services 2020-2022	(11) Goods 2011-2022	(12) Goods 2011-2015	(13) Goods 2016-2019	(14) Goods 2020-2022	(15) Goods 2020-2022
Labour	0.369***	0.387***	0.359***	0.351***	0.369***	0.521***	0.587***	0.554***	0.444***	0.493***	0.312***	0.327***	0.304***	0.293***	0.309***
	(16.29)	(15.17)	(14.38)	(11.11)	(11.52)	(7.97)	(8.19)	(8.00)	(7.09)	(7.27)	(18.36)	(15.19)	(10.33)	(11.14)	(10.33)
Materials	0.497***	0.455***	0.368***	0.472***	0.469***	0.326***	0.292***	0.323***	0.328***	0.334***	0.524***	0.542***	0.514***	0.361***	0.336***
	(186.16)	(97.58)	(6.11)	(9.99)	(6.27)	(9.74)	(3.22)	(7.38)	(4.29)	(4.49)	(18.63)	(120.73)	(13.84)	(5.34)	(3.91)
Tangible Capital	0.0569***	0.0111***	-0.00929	0.0424**	0.0635**	0.0370***	0.0241	0.0564**	0.0711*	0.0717*	0.0346***	0.0540***	0.0248**	0.0586***	0.0221
	(16.24)	(2.66)	(-0.44)	(2.41)	(2.39)	(3.28)	(0.61)	(2.09)	(1.81)	(1.86)	(2.76)	(5.33)	(2.21)	(2.67)	(0.72)
Research & Development	0.0401***	0.0421***	0.0432***	0.0299***	0.0385***	0.0581	0.0879**	0.0372	0.0386	0.0637	0.0326***	0.0267***	0.0442***	0.0232**	0.0291***
	(4.02)	(3.96)	(3.44)	(2.61)	(3.31)	(1.55)	(2.27)	(1.25)	(1.01)	(1.56)	(4.43)	(2.89)	(3.79)	(2.01)	(2.85)
Software & Databases	0.00874*	0.00821*	0.0131**	0.00517	0.00205	0.0360**	0.0436*	0.0329	0.0296	0.0184	0.00536	0.00268	0.0109**	0.00541	0.00364
	(1.80)	(1.70)	(2.16)	(0.74)	(0.28)	(2.27)	(1.92)	(1.59)	(1.29)	(0.83)	(1.50)	(0.65)	(2.28)	(0.75)	(0.53)
Firm-Specific Human Capital	0.0293***	0.0336***	0.0377***	0.00925	0.00734	0.0115	-0.00793	0.0192	0.00899	0.00466	0.0296***	0.0349***	0.0370***	0.00825	0.00732
	(4.52)	(4.77)	(3.88)	(0.95)	(0.74)	(0.58)	(-0.21)	(0.73)	(0.33)	(0.20)	(4.98)	(4.39)	(4.48)	(0.79)	(0.71)
Brand Value	0.00671**	0.00452	0.00938*	0.00798	0.00335	-0.00180	-0.000329	-0.0112	0.00509	0.00233	0.00791**	0.00608*	0.0108**	0.00816	0.00335
	(2.07)	(1.27)	(1.85)	(1.50)	(0.57)	(-0.12)	(-0.02)	(-0.71)	(0.28)	(0.13)	(2.50)	(1.80)	(2.27)	(1.55)	(0.57)
Covid					0.0769***					0.0538					0.0790***
					(3.14)					(1.46)					(3.23)
No. of Firms x Years	10,543	4,369	3,633	2,541	2,299	1,750	668	623	459	411	8,793	3,701	3,010	2,082	1,888

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B8. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% R&D firms, Extended Model Specification.

	(1) ME 2011-2022	(2) ME 2011-2015	(3) ME 2016-2019	(4) ME 2020-2022	(5) ME 2020-2022	(6) Services 2011-2022	(7) Services 2011-2015	(8) Services 2016-2019	(9) Services 2020-2022	(10) Services 2020-2022	(11) Goods 2011-2022	(12) Goods 2011-2015	(13) Goods 2016-2019	(14) Goods 2020-2022	(15) Goods 2020-2022
Labour	0.514***	0.512***	0.509***	0.524***	0.530***	0.559***	0.563***	0.546***	0.571***	0.575***	0.423***	0.421***	0.422***	0.428***	0.436***
	(38.02)	(51.19)	(39.71)	(41.73)	(37.59)	(31.62)	(31.31)	(27.46)	(29.63)	(26.78)	(48.87)	(28.80)	(27.67)	(23.06)	(20.09)
Materials	0.411***	0.395***	0.372***	0.254***	0.385***	0.289***	0.303***	0.318***	0.321***	0.206***	0.499***	0.490***	0.523***	0.498***	0.454***
	(260.99)	(7.85)	(9.16)	(3.97)	(7.46)	(13.23)	(15.44)	(367.47)	(7.08)	(5.16)	(485.73)	(10.54)	(180.41)	(102.98)	(7.20)
Tangible Capital	0.0744***	0.0575***	0.0147	0.0769***	0.0577***	0.0564***	0.0385***	0.0753***	0.0641***	0.0734***	0.0562***	0.0506***	0.0673***	0.0687***	0.0303**
	(27.05)	(5.12)	(0.54)	(3.61)	(4.01)	(6.55)	(4.49)	(64.47)	(2.98)	(3.04)	(34.83)	(2.92)	(20.73)	(20.46)	(2.04)
Research & Development	-0.000308	-0.000397	-0.000535	0.0000241	0.000933	0.00135	0.00244	-0.00000125	0.000965	0.00283	-0.00160*	-0.00238	-0.00108	-0.000748	-0.000609
	(-0.31)	(-0.27)	(-0.32)	(0.02)	(0.55)	(0.66)	(1.07)	(-0.00)	(0.32)	(0.76)	(-1.72)	(-1.47)	(-0.74)	(-0.45)	(-0.32)
Software & Databases	0.0192***	0.0186***	0.0226***	0.0151***	0.0153***	0.0301***	0.0299***	0.0324***	0.0272***	0.0253***	0.00827***	0.00709***	0.0124***	0.00336	0.00478
	(6.67)	(7.41)	(8.22)	(4.63)	(4.76)	(9.12)	(4.59)	(4.80)	(5.56)	(5.01)	(3.42)	(2.74)	(4.00)	(1.13)	(0.94)
Firm-Specific Human Capital	0.0181***	0.0187***	0.0185***	0.0165***	0.0144***	0.0207***	0.0200***	0.0232***	0.0176**	0.0120*	0.0143***	0.0148***	0.0134***	0.0150***	0.0147***
	(7.38)	(5.78)	(4.78)	(4.60)	(3.23)	(4.46)	(3.23)	(3.15)	(2.46)	(1.79)	(5.54)	(4.89)	(4.49)	(4.46)	(3.89)
Brand Value	0.00562***	0.00619**	0.00636**	0.00404	0.00654**	0.00933***	0.0116**	0.0119**	0.00128	0.00606	0.00349**	0.00305	0.00246	0.00656*	0.00753**
	(3.11)	(2.54)	(2.56)	(1.54)	(2.05)	(2.59)	(2.47)	(2.53)	(0.27)	(1.39)	(2.00)	(1.06)	(0.82)	(1.71)	(2.49)
Covid					0.0666**					0.0805***					0.0404***
					(2.34)					(2.84)					(3.01)
No. of Firms x Years	56,056	24,420	19,429	12,207	11,432	24,905	10,585	8,712	5,608	5,247	31,151	13,835	10,717	6,599	6,185

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B9. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% S&D firms, Extended Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	ME	ME	ME	ME	ME	Services	Services	Services	Services	Services	Goods	Goods	Goods	Goods	Goods
	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022
Labour	0.361***	0.378***	0.363***	0.326***	0.348***	0.456***	0.500***	0.468***	0.379***	0.428***	0.261***	0.265***	0.267***	0.243***	0.253***
	(20.25)	(14.97)	(16.09)	(10.84)	(13.15)	(12.17)	(11.02)	(9.68)	(8.61)	(9.55)	(13.95)	(11.46)	(11.24)	(8.62)	(8.81)
Materials	0.478***	0.479***	0.462***	0.483***	0.479***	0.374***	0.381***	0.366***	0.415***	0.400***	0.551***	0.360***	0.529***	0.550***	0.534***
	(177.06)	(128.10)	(18.77)	(8.86)	(10.00)	(8.59)	(4.49)	(7.03)	(10.45)	(5.02)	(31.66)	(4.32)	(22.91)	(7.02)	(7.45)
Tangible Capital	0.0620***	0.0559***	0.0478***	0.0492**	0.0575**	0.0359**	0.0248	0.0424***	0.0692***	0.0532*	0.0622***	0.0383	0.0302***	0.0499*	0.0539**
	(27.21)	(16.78)	(11.30)	(2.34)	(2.13)	(2.31)	(0.83)	(2.64)	(2.78)	(1.78)	(5.95)	(1.18)	(4.70)	(1.65)	(1.97)
Research & Development	0.00385	0.00321	0.00680**	0.000888	0.00204	0.00746	0.0107	0.0103*	0.00000436	0.00244	0.00181	-0.00286	0.00759**	0.000965	0.000466
	(1.39)	(0.91)	(2.06)	(0.26)	(0.54)	(1.53)	(1.52)	(1.86)	(0.00)	(0.38)	(0.72)	(-0.72)	(2.05)	(0.23)	(0.11)
Software & Databases	0.0539***	0.0414**	0.0625***	0.0655***	0.0590***	0.0966***	0.0911***	0.105***	0.0986***	0.0836***	0.0341***	0.0152	0.0463***	0.0530***	0.0527***
	(5.08)	(2.38)	(4.90)	(4.14)	(3.57)	(4.39)	(3.20)	(4.36)	(3.02)	(2.73)	(3.11)	(1.02)	(3.58)	(3.48)	(3.65)
Firm-Specific Human Capital	0.0202**	0.0276***	0.0173*	0.0120	0.00553	-0.0101	-0.0177	-0.0139	-0.000315	-0.00883	0.0293***	0.0383***	0.0264***	0.0131	0.00922
	(2.56)	(2.72)	(1.69)	(1.17)	(0.56)	(-0.72)	(-0.86)	(-0.72)	(-0.02)	(-0.51)	(3.95)	(3.77)	(3.03)	(1.17)	(0.77)
Brand Value	0.0105***	0.0111**	0.00981*	0.00997*	0.00963	0.0210**	0.0270**	0.0189*	0.0144	0.0132	0.00852*	0.00906*	0.00766	0.0113*	0.0108*
	(2.79)	(2.21)	(1.88)	(1.81)	(1.50)	(2.43)	(2.02)	(1.88)	(1.31)	(1.23)	(1.80)	(1.77)	(1.35)	(1.84)	(1.75)
Covid					0.0574***					0.0419					0.0453**
					(3.67)					(1.37)					(2.12)
No. of Firms x Years	9,900	3,949	3,553	2,398	2,159	3,371	1,338	1,212	821	739	6,529	2,611	2,341	1,577	1,420

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B10. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% S&D firms, Extended Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	ME	ME	ME	ME	ME	Services	Services	Services	Services	Services	Goods	Goods	Goods	Goods	Goods
	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022	2011-2022	2011-2015	2016-2019	2020-2022	2020-2022
Labour	0.526***	0.524***	0.518***	0.543***	0.546***	0.571***	0.571***	0.556***	0.597***	0.595***	0.441***	0.443***	0.436***	0.444***	0.455***
	(43.39)	(40.54)	(38.32)	(30.70)	(29.06)	(29.86)	(27.33)	(24.42)	(20.87)	(21.05)	(41.45)	(23.50)	(33.60)	(19.06)	(24.17)
Materials	0.408***	0.254***	0.411***	0.397***	0.380***	0.232***	0.317***	0.260***	0.284***	0.266***	0.501***	0.486***	0.480***	0.351***	0.479***
	(157.44)	(5.06)	(135.66)	(5.92)	(6.91)	(8.88)	(7.04)	(12.63)	(58.88)	(10.57)	(206.35)	(10.70)	(37.83)	(5.67)	(8.55)
Tangible Capital	0.0749***	0.0498***	0.0950***	0.0647***	0.0592***	0.0881***	0.0622***	0.0136	0.0520***	0.0738***	0.0662***	0.0450**	0.0355***	0.0790***	0.0561**
	(48.12)	(3.99)	(22.62)	(3.56)	(2.69)	(19.27)	(5.19)	(1.22)	(6.74)	(4.11)	(31.42)	(2.34)	(7.73)	(3.64)	(2.04)
Research & Development	0.00128*	0.00148	0.0000650	0.00252	0.00303**	0.00167	0.00228	-0.000624	0.00390	0.00480	0.00107	0.00132	0.000413	0.00141	0.00159
	(1.76)	(1.05)	(0.04)	(1.33)	(1.99)	(0.87)	(0.70)	(-0.17)	(1.26)	(1.44)	(1.15)	(0.90)	(0.22)	(0.72)	(0.88)
Software & Databases	0.0162***	0.0164***	0.0191***	0.0118***	0.0117***	0.0271***	0.0286***	0.0291***	0.0216***	0.0189**	0.00621**	0.00537**	0.00975***	0.00277	0.00425
	(7.66)	(6.58)	(6.42)	(4.06)	(3.40)	(5.40)	(7.08)	(5.70)	(3.80)	(2.43)	(2.15)	(2.22)	(2.64)	(0.67)	(1.10)
Firm-Specific Human Capital	0.0193***	0.0197***	0.0208***	0.0164***	0.0148***	0.0236***	0.0230***	0.0265***	0.0191***	0.0137**	0.0148***	0.0153***	0.0150***	0.0138***	0.0139***
	(8.57)	(7.52)	(6.36)	(4.69)	(4.85)	(5.27)	(4.56)	(4.28)	(2.89)	(2.29)	(6.45)	(4.84)	(5.33)	(5.53)	(3.55)
Brand Value	0.00497***	0.00521**	0.00611**	0.00366	0.00566**	0.00729*	0.00961**	0.00998**	-0.000326	0.00454	0.00370**	0.00292	0.00343	0.00643**	0.00689**
	(2.88)	(2.10)	(2.39)	(1.40)	(2.10)	(1.88)	(2.17)	(2.37)	(-0.08)	(0.90)	(2.10)	(1.57)	(1.48)	(2.55)	(2.54)
Covid					0.0687***					0.0798***					0.0514***
					(3.51)					(8.18)					(4.97)
No. of Firms x Years	56,699	24,840	19,509	12,350	11,572	23,284	9,915	8,123	5,246	4,919	33,415	14,925	11,386	7,104	6,653

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B11. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% R&D firms, Extended Model Specification.

	(1) Goods Total	(2) Manufacturing Total	(3) High-Tech	(4) Medium-Tech	(5) Low-Tech	(6) Other Goods	(7) Services Total	(8) Wholesale & Retail Trade	(9) Transportation & Storage	(10) IC	(11) Professional Services	(12) Other Services
Labour	0.312***	0.328***	0.347***	0.319***	0.281***	0.162	0.521***	0.163	0.234**	0.738***	0.670***	0.492***
	(19.00)	(18.18)	(12.97)	(9.31)	(6.52)	(1.59)	(9.14)	(0.61)	(2.19)	(9.20)	(7.78)	(4.17)
Materials	0.500***	0.506***	0.479***	0.550***	0.557***	0.572***	0.327***	0.894***	0.435***	0.226***	0.218***	0.303***
	(57.73)	(111.52)	(38.07)	(285.88)	(12.17)	(25.91)	(8.68)	(13.02)	(3.74)	(8.14)	(8.57)	(7.58)
Tangible Capital	0.0120	0.0223***	-0.00431	0.0480***	0.0872***	0.0770*	0.0391**	-0.113**	0.0463	0.00795	0.0389*	0.00241
	(1.51)	(4.56)	(-0.50)	(7.02)	(6.75)	(1.85)	(2.35)	(-2.56)	(0.96)	(0.57)	(1.70)	(0.08)
Research & Development	0.0326***	0.0331***	0.0542***	0.0207	-0.0301	0.0554	0.0581*	-0.142	0.0985	0.0544	-0.0161	0.0193
	(4.44)	(4.63)	(5.07)	(1.62)	(-1.27)	(1.11)	(1.93)	(-0.96)	(1.56)	(1.02)	(-0.27)	(0.42)
Software & Databases	0.00536	0.00361	0.00249	0.00278	0.00423	0.0186	0.0360**	-0.00468	-0.0191	0.0394**	0.0111	0.0945
	(1.45)	(1.02)	(0.47)	(0.35)	(0.47)	(0.92)	(1.99)	(-0.03)	(-0.39)	(1.97)	(0.41)	(1.61)
Firm-Specific Human Capital	0.0296***	0.0303***	0.0256***	0.0400***	0.0361**	0.0300	0.0115	-0.0833	-0.0707	0.00167	0.0176	0.0228
	(4.51)	(5.27)	(2.80)	(3.34)	(2.04)	(1.22)	(0.53)	(-0.90)	(-0.63)	(0.06)	(0.33)	(0.22)
Brand Value	0.00791**	0.00942***	0.00406	0.0120**	0.0169**	-0.00301	-0.00180	-0.109	0.0463	-0.00377	0.0282	-0.0141
	(2.50)	(3.18)	(0.91)	(2.28)	(2.20)	(-0.19)	(-0.15)	(-0.83)	(0.76)	(-0.20)	(1.06)	(-0.19)
No. of Firms x Years	8,793	8,476	5,410	2,160	906	317	1,750	95	154	830	338	333

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B12. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% R&D firms, Extended Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Goods Total	Manufacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.423***	0.421***	0.441***	0.446***	0.398***	0.415***	0.559***	0.491***	0.470***	0.652***	0.677***	0.495***
	(32.04)	(27.82)	(21.05)	(22.51)	(26.56)	(13.61)	(40.07)	(8.64)	(13.95)	(24.20)	(28.61)	(16.81)
Materials	0.507***	0.509***	0.517***	0.482***	0.517***	0.467***	0.295***	0.455***	0.343***	0.287***	0.179***	0.300***
	(201.16)	(15.71)	(25.14)	(19.94)	(12.17)	(386.07)	(19.73)	(4.87)	(10.41)	(13.54)	(10.89)	(15.95)
Tangible Capital	0.0679***	0.0475***	0.0543***	0.0281***	0.0530***	0.0749***	0.0532***	0.0776***	0.0514***	0.0198*	0.0370***	0.0756***
	(34.89)	(2.87)	(11.36)	(3.63)	(4.45)	(59.42)	(9.69)	(6.18)	(5.40)	(1.84)	(5.61)	(17.01)
Research & Development	-0.00160	0.000616	-0.00132	0.00130	0.00140	-0.0110***	0.00135	0.00166	0.0151***	-0.00667	-0.00350	0.0105*
	(-1.37)	(0.38)	(-0.40)	(0.68)	(0.60)	(-2.60)	(0.53)	(0.41)	(2.60)	(-1.30)	(-1.00)	(1.91)
Software & Databases	0.00827***	0.0103***	0.00985**	0.00735*	0.0144***	0.00521	0.0301***	0.0221***	0.0312***	0.0164**	0.0267***	0.0382***
	(3.90)	(3.71)	(2.14)	(1.95)	(4.09)	(0.87)	(9.87)	(2.63)	(3.48)	(1.99)	(5.35)	(4.86)
Firm-Specific Human Capital	0.0143***	0.0147***	0.0143**	0.0112***	0.0146***	0.0106	0.0207***	-0.0197*	0.0314***	0.0308***	0.0218***	0.0292**
	(5.64)	(4.98)	(2.38)	(3.25)	(3.34)	(1.39)	(4.72)	(-1.84)	(3.10)	(3.20)	(3.90)	(2.46)
Brand Value	0.00349**	0.00114	0.00299	-0.000505	-0.000523	0.00845**	0.00933***	0.0121	-0.0125*	0.0209**	0.00326	0.0149**
	(2.14)	(0.51)	(1.10)	(-0.19)	(-0.13)	(2.39)	(4.22)	(1.10)	(-1.80)	(2.39)	(0.63)	(2.55)
No. of Firms x Years	31,151	23,956	6,443	9,963	7,550	7,195	24,905	3,298	3,827	3,611	8,662	5,507

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B13. Intangible Capital and Firm-Level Productivity – LP Estimations for Top 20% S&D firms, Extended Model Specification.

	(1) Goods Total	(2) Manufacturing Total	(3) High-Tech	(4) Medium-Tech	(5) Low-Tech	(6) Other Goods	(7) Services Total	(8) Wholesale & Retail Trade	(9) Transportation & Storage	(10) IC	(11) Professional Services	(12) Other Services
Labour	0.261***	0.277***	0.342***	0.280***	0.179***	0.198***	0.456***	0.463***	0.207**	0.677***	0.720***	0.514***
	(12.09)	(13.28)	(10.42)	(7.15)	(4.59)	(3.78)	(12.12)	(5.08)	(2.33)	(8.46)	(9.65)	(7.78)
Materials	0.530***	0.578***	0.515***	0.626***	0.642***	0.477***	0.393***	0.615***	0.405***	0.343***	0.169***	0.333***
	(123.01)	(65.60)	(16.97)	(199.81)	(70.17)	(8.55)	(11.17)	(7.44)	(5.40)	(4.83)	(6.63)	(10.76)
Tangible Capital	0.0382***	0.0599***	0.0288**	0.0583***	0.0945***	0.0653***	0.0459***	0.0157	0.0680**	0.000741	0.0404**	0.0609***
	(11.10)	(41.02)	(2.29)	(20.89)	(9.38)	(3.68)	(4.63)	(0.41)	(1.98)	(0.03)	(2.30)	(3.39)
Research & Development	0.00181	-0.00119	-0.0000831	-0.00835*	-0.000492	0.00850	0.00746	-0.00861	0.00959	-0.000241	-0.00502	0.0287***
	(0.68)	(-0.39)	(-0.02)	(-1.70)	(-0.11)	(1.57)	(1.46)	(-0.98)	(1.12)	(-0.02)	(-0.49)	(2.96)
Software & Databases	0.0341***	0.0285***	0.0342***	0.0333*	0.0209	0.0488	0.0966***	0.0940**	0.129**	0.0969*	0.00433	0.0885**
	(3.23)	(3.02)	(2.81)	(1.67)	(0.86)	(1.13)	(4.18)	(2.47)	(2.13)	(1.69)	(0.08)	(2.49)
Firm-Specific Human Capital	0.0293***	0.0260***	0.0225**	0.0373***	0.0236	0.0976**	-0.0101	-0.0342	0.000652	0.00241	-0.0265	-0.0136
	(4.75)	(3.65)	(2.46)	(2.84)	(1.42)	(2.40)	(-0.71)	(-1.21)	(0.02)	(0.08)	(-0.87)	(-0.37)
Brand Value	0.00852*	0.00900**	0.00759*	0.00537	0.0316***	0.00938	0.0210***	0.0166	0.0226	0.0224	0.0358**	0.0124
	(1.90)	(2.21)	(1.69)	(0.60)	(3.21)	(0.81)	(2.79)	(0.54)	(1.27)	(1.09)	(2.01)	(0.65)
No. of Firms x Years	6,529	5,356	2,895	1,548	913	1,173	3,371	460	516	784	521	1,090

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Table B14. Intangible Capital and Firm-Level Productivity – LP Estimations for Lower 80% S&D firms, Extended Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Goods Total	Manufacturing Total	High-Tech	Medium-Tech	Low-Tech	Other Goods	Services Total	Wholesale & Retail Trade	Transportation & Storage	IC	Professional Services	Other Services
Labour	0.441***	0.436***	0.452***	0.445***	0.425***	0.452***	0.571***	0.508***	0.501***	0.667***	0.676***	0.487***
	(38.99)	(41.03)	(26.30)	(20.15)	(16.95)	(15.15)	(27.64)	(8.01)	(9.84)	(17.85)	(32.81)	(13.00)
Materials	0.502***	0.481***	0.485***	0.465***	0.525***	0.430***	0.290***	0.448***	0.201***	0.279***	0.267***	0.292***
	(173.68)	(138.99)	(114.87)	(18.86)	(359.89)	(162.42)	(30.55)	(6.10)	(3.78)	(10.43)	(70.38)	(24.71)
Tangible Capital	0.0668***	0.0268***	0.0220***	0.0254*	0.0707***	0.0404***	0.0452***	0.0852***	0.00892	0.0267***	0.0837***	0.0742***
	(37.56)	(7.28)	(6.44)	(1.71)	(64.35)	(9.79)	(7.95)	(3.86)	(0.49)	(2.65)	(28.41)	(15.74)
Research & Development	0.00107	0.00233**	0.00428*	0.00202	-0.000884	-0.00962**	0.00167	0.00222	0.0209***	-0.00338	-0.00402	0.00855
	(1.06)	(2.04)	(1.73)	(1.23)	(-0.37)	(-2.47)	(0.80)	(0.29)	(2.70)	(-0.61)	(-1.33)	(1.36)
Software & Databases	0.00621***	0.00934***	0.0102***	0.00574*	0.0143***	-0.00175	0.0271***	0.0197	0.0267**	0.0166	0.0259***	0.0380***
	(2.73)	(3.58)	(2.81)	(1.92)	(2.86)	(-0.35)	(5.91)	(1.36)	(2.03)	(1.60)	(4.93)	(3.93)
Firm-Specific Human Capital	0.0148***	0.0159***	0.0183***	0.0117***	0.0152***	0.00922	0.0236***	-0.0183	0.0369**	0.0303***	0.0236**	0.0328***
	(4.88)	(6.73)	(2.61)	(2.69)	(2.81)	(1.34)	(3.93)	(-1.32)	(2.16)	(3.12)	(2.42)	(3.60)
Brand Value	0.00370**	0.00272	0.00459	0.000963	-0.000536	0.00319	0.00729**	0.0101	-0.0174**	0.0163***	0.00204	0.0129
	(2.48)	(1.34)	(1.56)	(0.32)	(-0.12)	(0.69)	(2.02)	(0.82)	(-2.41)	(2.58)	(0.48)	(1.62)
No. of Firms x Years	33,415	27,076	8,958	10,575	7,543	6,339	23,284	2,933	3,465	3,657	8,479	4,750

Notes: Estimated coefficients (t-values in parentheses). ***, **, *: p<0.01, p<0.05, p<0.1.

Appendix C. Replication Tables

Table C1. Composition of Investment: Replication of Table 1 in Friesenbichler et al (2025) with MIP data

	NACE rev. 2	Share in Total	R&D expenditure	Software & database expenditure	Firm-specific training expenditure	Advertising & marketing expenditure	Tangible capital expenditure
Goods	**5-39**	**59.9**	**33.5**	**6.1**	**1.8**	**16.7**	**41.9**
Manufacturing	10-33	51.1	39.0	6.3	1.9	18.6	34.3
High-tech manufacturing	21, 26, 30	9.3	53.4	7.1	1.5	18.6	19.3
Medium-tech manufacturing	20, 27-29	28.9	45.5	6.3	1.8	17.0	29.3
Low-tech manufacturing	10-19, 24-25, 31-33	12.9	14.2	5.5	2.2	22.0	56.1
Other goods	5-9, 35-39	8.8	1.4	5.4	1.3	5.7	86.1
Services	**46, 49-53, 58-66, 69-74, 78-82**	**40.1**	**10.1**	**16.3**	**3.2**	**11.6**	**58.8**
Wholesale trade, transportation, storage	46, 49-53	15.8	1.7	5.9	2.1	8.5	81.8
Professional, technical, scientific services	69-74	5.6	23.1	11.1	5.5	6.6	53.7
Information & communication	58-63	10.0	19.0	26.6	2.6	15.7	36.0
Financial services	64-66	7.3	7.3	29.6	4.2	17.0	41.9
Other services	78-82	1.4	4.2	12.7	4.8	10.3	68.0
Total	**5-39, 46, 49-53, 58-66, 69-74, 78-82**	**100.0**	**24.1**	**10.2**	**2.3**	**14.7**	**48.7**

Appendix D: Structural Business Survey versus Community Innovation Survey

The existing literature can be grouped into two strands depending on the use of their datasets. On the one hand, there are those studies that investigate the official Structural Business Services data from the national accounts and Eurostat. Such studies include the papers by Kaus et al. (2024), Friesenbichler et al. (2025), Le Mouel and Schiersch (2024), and Bessen and Wang (2024). Such studies have a representative coverage of the national account's intangibles: R&D and Software. In general, these studies face the limitation of incomplete coverage of other intangibles, such as firm-specific human capital, branding, and organisational capital. Moreover, these studies focus on R&D and software investments, which were reported and activated in the firms' balance sheets. This leads to the following peculiar situation in the research findings of these studies: they conclude that only a very few firms invest in software and intangibles per se. E.g., the paper by Friesenbichler et al. (2025) for Austria concludes that only 31.1% of firms invested in intangibles between 2008 and 2017. Kaus et al. (2024) state that, in the German case, 30% of firms between 2012 and 2015 did not invest in intangibles. Bessen and Wang (2024), in the US case, conclude that apart from the Top 250 firms, almost no firms invest in R&D and own-account S&D.

On the other hand, there are those studies that rely on a representative firm-level analysis, using data from the Community and Innovation Survey or the MIP for the German case. These studies have access to a more complete set of national accounts intangibles (R&D and Software) and non-national accounts intangibles (firm-specific human capital and brand value). Moreover, because the survey data capture account expenditure on software investment, it is less prone to measurement error (Nonnis et al. 2025). Such studies, which use data from the Mannheim Innovation Panel (MIP) to analyse the effects of intangibles on the productivity of German firms, include Crass and Peter (2014), Rammer and Peters (2016), and Roth et al. (2023). These studies conclude that a wide range of firms invest in software. Similarly, our paper finds that 92% of firms invest in Software, 90% in firm-specific human capital, and 88% in brand value. (see here Table E2 in Appendix E). Moreover, our paper finds that the investment ratios in R&D (24.1% vs. 7%) and S&D (10.2% vs. 3.2%) are threefold those reported in the study on Austria by Friesenbichler et al. (2025) (see Table C1 in Appendix C).

Appendix E. Share of Top firms

Table E1. Share of Top 20%, Top 10%, Top 5% and Top 1% firms

sum for net sample (bn€)	Share Top-20%				Share Top-10%				Share Top-5%				Share Top-1%			
	R&D	S&D	HV	BV	R&D	S&D	HV	BV	R&D	S&D	HV	BV	R&D	S&D	HV	BV
High-tech	99.9	98.7	98.4	99.6	99.5	97.7	97.8	99.2	98.1	92.9	92.9	97.3	90.9	80.2	79.5	90.6
Medium-tech	98.8	92.5	94.8	97.6	96.7	89.9	93.0	96.3	89.5	71.9	81.3	89.2	63.7	50.2	70.3	67.1
Low-tech	95.6	89.0	84.9	97.5	88.3	85.5	81.7	95.8	64.4	52.5	52.7	85.1	30.8	15.3	9.2	45.0
Other goods	97.9	97.1	94.5	96.2	96.8	95.2	92.7	93.3	90.5	86.1	80.1	79.5	73.5	50.2	48.7	38.0
Goods	99.7	97.3	96.8	99.1	99.1	95.9	95.8	98.5	97.0	87.5	87.8	95.0	87.9	69.6	72.2	83.3
Trade	90.7	96.0	89.7	98.6	92.1	94.9	92.1	97.4	68.6	83.6	71.4	92.9	0.0	55.4	43.5	81.1
Transport	98.7	98.6	98.7	99.2	98.0	97.7	98.3	99.0	93.0	92.8	95.0	96.1	55.8	74.4	87.8	82.5
IC services	99.6	99.7	98.2	99.4	98.7	99.6	97.9	99.1	96.6	98.8	93.2	96.8	91.6	96.3	85.1	90.1
Professional services	84.3	78.4	93.5	86.4	74.1	81.1	96.0	85.0	48.7	49.5	85.3	67.3	6.9	35.4	83.1	42.4
Other services	99.0	99.3	98.3	99.2	98.3	99.0	98.2	98.6	93.9	96.8	92.2	93.8	65.4	82.0	72.3	76.0
Services	98.9	99.0	97.3	99.0	98.0	98.9	97.6	98.4	94.4	96.4	91.4	94.7	82.7	89.0	80.5	82.7
Total	99.6	98.4	97.0	99.1	99.0	97.8	96.6	98.5	96.7	93.2	89.3	94.9	87.4	82.1	75.7	83.1

Table E2. Share of Firms that have no intangible capital stock

share in net sample (%)	Share CS=0 in %			
	R&D	S&D	HV	BV
High-tech	15	4	6	8
Medium-tech	41	8	10	12
Low-tech	50	12	22	11
Other goods	70	11	8	20
Goods	**41**	**8**	**11**	**12**
Trade	67	8	11	7
Transport	74	17	12	22
IC services	33	5	11	8
Professional services	55	4	7	12
Other services	64	11	12	10
Services	**58**	**8**	**10**	**12**
Total	**47**	**8**	**10**	**12**

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