Discussion Paper No. 13-062

The Contribution of Intangible Assets to Sectoral Productivity Growth in the EU

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Non-Technical Summary

Knowledge creation is a key driver of growth in modern economies. The creation of knowledge is often comparable to the accumulation of tangible capital: In the current period, investments are made in order to yield rents not only in the present but also in future years. Economists have been investigating the effects of investments in knowledge for a long time. However, only in recent years were efforts made to study intangible capital in a way consistent with the national accounts (NA). Intangible capital includes expenditures on research and development (R&D), firm-specific human capital, expenditures on new financial products, new architectural and engineering designs, expenditures on market research, advertising expenditures, own-account development of organizational structures and purchased organizational structures. In contrast to investments in both information and communication technologies (ICT) and Non-ICT investments such as machinery or transport equipment, the intangible investments mentioned above are not currently included in the national accounts. However, from 2014, expenditures on R&D will be part of the national accounts.

The combined efforts of multiple international projects have already established a harmonized database of intangible capital at the business sector level. This database is publicly available on the INTAN-Invest platform for the period 1995 to 2007. Using these data, we are able to calculate sectoral level data for 11 industries of 10 EU countries for the first time. With this sectoral breakdown we find that the share of intangible investment in value added is higher in the goods producing sector than in the service sector.

In order to evaluate the productivity effects of intangible capital, we use two different methodologies. First, in a growth accounting framework we show that intangibles are key drivers for productivity growth particularly in the manufacturing and financial intermediation sectors. The productivity growth in manufacturing is largely driven by expenditures on R&D. In an international comparison there are nevertheless remarkable differences. In the UK we see a large positive contribution of intangibles to labor productivity growth in the business services sector.
Second, an econometric analysis relaxes the growth accounting assumption that all input factors earn their marginal product. Using this alternative methodology, we see output elasticities of intangible capital ranging from 0.1 to 0.2. The output elasticity of intangibles is the percentage increase in output for a one percent increase in intangible capital input. The results are larger than the factor compensation share of intangible capital. This could be an indicator of unmeasured complementarities (e.g. with ICT) or spillovers of intangible capital. Our calculated elasticities of intangible capital are of a smaller magnitude than those found in previous studies that are based on total business sector data.

Das Wichtigste in Kürze

Wissen ist ein zentraler Wachstumsmotor in modernen Volkswirtschaften. Häufig entsteht Wissen analog zu Sachkapital: In der Gegenwart werden Investitionen getätigt, von denen man sich nicht nur im gleichen Jahr sondern auch in zukünftigen Jahren Erträge erhofft. Die Investitionswirkungen von Wissensbildung haben Ökonomen schon lange beschäftigt, aber erst in jüngster Zeit hat man versucht, immaterielles Kapital systematisch in einem Rahmen zu untersuchen, der in die Volkswirtschaftliche Gesamtrechnung (VGR) integrierbar ist. Dabei umfassen Investitionen in immaterielles Kapital Ausgaben für wissenschaftliche Forschung und Entwicklung, firmengebundenes Humankapital, Ausgaben für Produktentwicklungen im Finanzsektor, neuartige architektonische und konstruktive Entwürfe, Ausgaben für Marktforschung, Ausgaben für markenbildende Werbung und firmeneigenes sowie zugekauftes Organisationskapital. Im Gegensatz zu den Investitionen in Informations- und Kommunikationstechnologien (IKT) und Nicht-IKT Investitionen (Maschinen, Transportmittel usw.), sind die zuvor genannten Komponenten des immateriellen Kapitals gegenwärtig nicht in der VGR enthalten. Ab 2014 werden zumindest die Ausgaben für Forschung und Entwicklung berücksichtigt.

Aus mehreren internationalen Projekten sind in den letzten Jahren harmonisierte Berechnungen für immaterielles Kapital auf gesamtwirtschaftlicher Ebene der EU-Länder hervorgegangen, die auf der INTAN-Invest Plattform öffentlich verfügbar sind. Wir nutzen die INTAN-Invest Plattform als Ausgangsbasis, um erstmals sektorale Daten zu immateriellem Kapital für 10 europäische Länder zu berechnen. Die Daten liegen für 11 Sektoren über den Zeitraum von 1995 bis 2007 vor. Mit den gegenwärtig möglichen Messungen ergibt sich, dass das Verhältnis von immateriellem Kapital zur Wertschöpfung im Verarbeitenden Gewerbe tendenziell höher als im Dienstleistungssektor ausfällt.

Zur Bestimmung der Produktivitätseffekte von immateriellem Kapital verwenden wir zwei unterschiedliche methodische Ansätze. Das Growth Accounting („Wachstumsbuchhaltung“) zeigt, dass immaterielles Kapital insbesondere im Verarbeitenden Gewerbe und im Kredit- und Versicherungsgewerbe produktivitätssteigernd wirkt. Ersteres lässt sich insbesondere durch die hohen Ausgaben für wissenschaftliche Forschung und Entwicklung im Verarbeitenden Gewerbe erklären. Im europäischen Vergleich zeigen sich dennoch gewisse Unterschiede. So hat immaterielles Kapital im Vereinigten Königreich (UK) auch im Bereich der Unternehmensdienstleistungen einen starken positiven Einfluss auf das Wachstum der Arbeitsproduktivität.
Ökonometrische Analysen heben die Annahme des Growth Accounting auf, dass sich die Produktivität von Kapital im Kapitalertrag widerspiegelt. Aus dieser Analyse ergeben sich Werte für die Outputelastizität von immateriellem Kapital zwischen 0,1 und 0,2. Die Outputelastizität gibt dabei an, um wie viel Prozent der Output steigt, wenn sich das immaterielle Kapital um ein Prozent erhöht. Die Werte liegen generell über der Faktorentlohnung für immaterielles Kapital. Dies gilt gemeinhin als Hinweis auf mögliche ungemessene Komplementaritäten (z.B. mit IKT) oder Spillovers. Die Effekte fallen aber erheblich geringer aus als die Ergebnisse aus früheren Studien nahelegen, die ausschließlich auf gesamtwirtschaftlichen Daten beruhen.

The Contribution of Intangible Assets to Sectoral Productivity Growth in the EU

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Abstract

In this paper we report on new data on intangible investment at the level of 1-digit NACE industries of 10 EU countries. The data are constructed as a sectoral breakdown of the INTAN-Invest database, which contains measures of intangible investment at the level of the aggregate business sector. With the sectoral data we assess the contribution of intangibles to productivity growth based on growth accounting and econometric estimation of production functions. The growth accounting contribution of intangibles to labor productivity growth is generally highest in manufacturing and finance. The estimated output elasticity of intangibles lies between 0.1 and 0.2, considerably below values found in previous research using aggregate data.

Keywords: Intangible Assets, Labor Productivity, Growth Accounting, Panel Regressions.

JEL Classification Numbers: E22, J24, O47.

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1 Introduction

During the past two decades, growth in aggregate productivity has been quite unevenly distributed across the advanced economies. While earlier work explored the effect of differences in ICT investment and in multifactor productivity, more recent work considers the role that investment in intangible assets plays in explaining cross-country differences in labor productivity growth. A smaller part of the intangible investments such as software are included in standard national accounts data and in international data provided, e.g., by the EU KLEMS project. Most intangible assets such as R&D, organizational capital and training are to date not treated as investment in national accounts (R&D is to be added according to SNA 2008). Estimates of intangible assets at the aggregate level of European countries have recently become available through the INTAN-Invest platform.

In this paper we make a first attempt to quantify the importance of intangible assets, defined from the perspective of national accounting, at the sectoral level of European countries. We provide a better understanding of the contribution of intangible assets to sectoral productivity growth in three ways: First, we describe the methodology of a new sectoral breakdown of the INTAN-Invest data for 14 European countries at the level of NACE 1-digit industries. Second, we present descriptive and growth accounting evidence for 10 countries on the magnitude of intangible investment and its contribution to labor productivity growth across sectors. Third, we estimate the output elasticity of intangibles econometrically and compare the results with those obtained in growth accounting.

Growth accounting reveals a non-negligible contribution of intangible assets to productivity growth. In most countries and sectors, it is equal or lower than the contribution of ICT for the period 1995 − 2007. In many countries, the ratio of intangible investment to value added and the contribution of intangible investment to labor productivity growth are highest in the manufacturing and financial intermediation sectors. In the UK, which attained high productivity growth during the period of observation, the contribution of intangibles turns out to be high in a broad range of sectors including services. The output elasticity of intangibles found in econometric estimation generally ranges between 0.1 and 0.2. These values are much lower than the results found with aggregate measures of intangibles. Depending on the specification, the output elasticity of intangibles exceeds their factor share by a fraction that lies between zero and two-thirds.

2 Related Research

While the concept of intangible capital has been used in economic research for a long time, the explicit attempt to quantify it in a way that can be integrated into national accounts was undertaken only recently. Corrado et al. (2005) made the main contribution setting out the approach for categorizing and quantifying intangible capital at the level of the national economy. In particular they set out criteria for treating some expenditures as investment rather than as intermediate inputs. Corrado et al. (2009) construct intangible capital estimates for the U.S. and use them in a growth accounting framework. Including previously unmeasured inputs generally lowers the measured growth in multifactor productivity (MFP) and raises the measured contribution of capital inputs to growth in labor productivity. With their data, Corrado et al. (2009) find that the contribution of intangible capital to growth in labor productivity is about equal to the contribution of tangibles. After accounting for intangibles, capital instead of MFP constitutes the dominant source of growth. Internationally comparable data on intangibles have been constructed based on the approach by Corrado et al. (2005) in the projects INNODRIVE (Piekkola (2011)) and COINVEST, funded by the European Commission, and by The Conference Board.[1] Recently the three teams published harmonized data on intangibles at the country level on the platform INTAN-Invest (Corrado et al. (2012)). COINVEST produced several studies on intangibles at the sectoral level with data for single countries or a small number of countries (see Haskel et al. (2010), Haskel and Pesole (2011) and Peters et al. (2010)). With UK data for the years $2000 - 2009$, Goodridge et al. (2012) find manufacturing to be the industry with the highest ratio of intangible investment to value added. Chun et al. (2012) compare Japanese with Korean data and find that the share of intangible investment in value added is higher in Japan for many industries. Meanwhile it turns out to be higher in some Korean service industries. Estimating the influence of intangibles on conventional MFP for Japan, the authors find a significant positive effect for the market economy but no clear effect for the service sector. Other country-specific growth accounting studies with intangibles at the sectoral level are Baldwin et al. (2012), Barnes and McClure (2009) as well as Fukao et al. (2009). In this paper we provide a first sectoral breakdown of intangible data for a larger set of European countries.

The econometric literature on the relationship between intangibles and labor productivity at the macroeconomic level is just beginning to emerge. Roth and Thum (2013) use INNODRIVE data for the aggregate of the nonfarm business sector of 13 European countries to estimate a production function. When accounting for intangibles, investment instead of growth in multifactor productivity becomes the dominant source of growth in their estimation. The coefficient of intangible investment in a constant-returns Cobb-Douglas function of about one quarter turns out to be a lot higher than the coefficient identified by the factor share in growth accounting. Using the INTAN-Invest data, Corrado et al. (2013) find a coefficient of similar, in some specifications even larger magnitude. They formally investigate the presence of spillovers that are suspected if the estimated marginal product of a factor exceeds the marginal product implied by the factor remuneration under competitive markets. Their results strongly support the possibility of spillovers. Moreover, they find evidence of a complementarity between intangible assets at the aggregate level and ICT capital at the sectoral level. Limitations of previous work using aggregate measures of intangibles are the small number of observations available for econometric estimation and the lack of information on heterogeneity of intangible assets across industries. The work by O'Mahony and Peng (2011) was one of the first to investigate the complementarity between ICT and intangible assets at the industry level. Their analysis is limited to investment in firm-specific human capital accumulated by training. In line with the work at the country level, it finds evidence of an output elasticity of firm-specific human capital exceeding its factor share and of complementarity between ICT and training. In this paper we compare results from growth accounting and econometric estimation with respect to the contribution of a broad range of intangible assets to growth based on industry-level data.

[1] http://www.conference-board.org/data/intangibles/.

3 Data Construction

3.1 Sources and Methods

The data for our analysis cover 10 European countries (listed in table A.2) for the period of 1995 to 2007. The data on output, non-ICT tangible capital, ICT and labor input are taken from the EU KLEMS database (O'Mahony and Timmer (2009)). The sectoral data on intangibles were compiled by the authors within the INDICSER project. The main source for computing sectoral measures of intangible investment was the INTAN-Invest database described by Corrado et al. (2012), which contains data at the level of the aggregate business sector for 7 different intangible assets not included in EU KLEMS: organizational capital, firm-specific human capital, R&D, new architectural and engineering designs, market research and advertising expenditure. Information about the own-account and the purchased component of organizational capital is used from INNODRIVE (see Table A.3). We apply sectoral information to the INTAN-Invest data to obtain estimates for investment in individual assets and total intangible investment at the level of 1-digit industries of the NACE rev. 1.1 classification. Table A.1 describes the industry coverage in detail.

In line with the principles used in INTAN-Invest, 20 percent of managers' wages are counted as own-account development of organizational structures (OKo). Investment in firm-specific human capital (FSHK) is split up among sectors using data on training costs, time spent on training and opportunity cost of training (for details see O'Mahony (2012)). New product development costs in the financial industry (NFP) from INTAN-Invest can be entirely allocated to sector J. Aggregate scientific R&D is broken down based on information from the OECD ANBERD and BERD data. A caveat applies to the treatment of the R&D sector itself ($K73$), since counting R&D output as investment may overestimate the accumulation of intangibles if a high share of this output is sold to other industries.

We consider as purchased assets investments in purchased organizational structures (OKp), new architectural and engineering designs (Arch), market research (MKTR), and advertising expenditure (ADV). We employ proportions from use tables at purchasers' prices from the World Input-Output Database (WIOD) described by Timmer (2012) to construct the sectoral breakdown of the aggregate values for these assets. We assume that for every category the weight of an industry in the total purchase of assets of a particular category equals the weight of that industry in the purchase of services from industry $K74$, other business services, which includes marketing, architecture advertising and consulting. Since $K74$ includes other sub-industries not relevant for intangibles we conducted sensitivity analysis with more precise NACE rev. 2 matrices, which are, however, not available across time so far (see Appendix B.5). Moreover our computations are based on the assumption that designs, marketing and advertising investment are entirely purchased assets (or that the proportion of own-account expenditure falling into a particular industry equals the proportion of purchased assets), which may represent a limitation.

For the construction of real intangible capital, investments are in general deflated with an index based on the deflator for value added from the EU KLEMS database. Training capital uses an earnings deflator (see O'Mahony (2012)). The detailed methodology for the construction of the sectoral intangible measures and the resulting adaptation of output and capital is described in the Appendix B. Tables 3.1 and 3.2 present descriptive statistics for the sectoral intangible data.

With the currently available data at the level of 1-digit industries of the NACE rev. 1.1 classification we consider that our sectoral breakdown reveals useful first insights on the sectoral distribution of intangible assets, the change in econometric results when using sectoral instead of aggregate data and the measurement challenges lying ahead. While some further adjustments may be feasible with NACE rev. 2 data, which are not yet available for all necessary components, we expect that a major step beyond the limitations currently faced will only be possible by building up sectoral estimates directly from national accounts and micro data. A reference set of sectoral data will most likely emerge in the future from intertwined efforts by research teams at several institutions, as was the case with the aggregate data on the INTAN-Invest platform.

3.2 Computation of Input and Output Measures

The industry-specific intangible capital stock series A_t are constructed using the well-known Perpetual Inventory Method (PIM):

$$A_{k,j,t} = (1 - \delta_k)A_{k,j,t-1} + I_{k,j,t}/Ip_t \tag{1}$$

where $I_{k,j,t}$ is nominal investment in intangible capital. Nominal investment is deflated by Ip_t, which is the same for all industries j and intangible assets k (except training). It is based on the value added price index for the total business sector (BS).[2] δ_k is the time- and industry-invariant depreciation rate of asset k taken from Corrado et al. (2012). The initial capital stock in year 1995 is derived from the following formula:

$$A_{k,j,1995} = Iq_{k,j,1995}/(\delta_k + \bar{g}) \tag{2}$$

where $Iq_{k,j,1995}$ is the real investment in 1995 in intangible asset k, $\bar{g}$ is the average growth rate of real value added in the total business sector between 1991 and 1999 (1995 – 1999 for the Czech Republic and Hungary) and δ_k is again the depreciation rate of asset k.

Because of the inclusion of intangible investment we have to adjust several EU KLEMS input and output variables. We adjust nominal value added as follows:

$$VA_{adj\ ,j,t} = VA_{j,t} + \sum_{k \in INT} I_{k,j,t}\ . \tag{3}$$

An adjusted value added deflator $VA\_P_{adj,j,t}$ is calculated as:

$$\Delta \ln VA\_P_{adj,j,t} = \bar{v}_{VA,j,t} \Delta \ln VA\_P_{j,t} + \bar{v}_{INT,j,t} \Delta \ln Ip\_INT_t \tag{4}$$

where $\bar{v}_{VA,j,t}$ is the two-period average share of nominal value added VA in adjusted value added and $\bar{v}_{INT,j,t}$ the two-period average share of nominal intangible investment I_{INT} in adjusted value added. The purchased intangibles (OKp, Arch, MKTR and ADV) increase value added in industry j due to the reduced amount of intermediate inputs. Gross output remains the same. The own-account intangibles (OKo, FSHK, NFP, and R&D) increase gross output and therefore value added of industry j (for an elaborate discussion see, e.g., Statistisches Bundesamt (2009, page 60)). We also have to recalculate the internal rate of return. First we compute the industry-specific adjusted total capital

[2] There are initial efforts to estimate specific investment price indices for intangibles (e.g. Corrado et al. (2011) and Copeland and Fixler (2012) for R&D).

compensation:

$$CAP_{adj\,j,t} = VA_{adj\,j,t} - LAB_{j,t} \tag{5}$$

where VA_{adj} denotes adjusted value added and LAB labor compensation. The nominal rate of return i for industry j is then defined as:

$$i_{j,t} = \frac{CAP_{adj\,j,t} + \sum_k (p^I_{k,j,t} - p^I_{k,j,t-1})A_{k,j,t} - \sum_k p^I_{k,j,t}\delta_{j,k}A_{k,j,t}}{\sum_k p_{k,j,t-1}A_{k,j,t}} \tag{6}$$

where $p^I_{k,j,t}$, $\delta_{k,j}$ and $A_{k,j,t}$ are the investment price index, the depreciation rate and the real stock of all tangible and intangible assets k.[3] Table A.3 gives a list of the 16 assets covered. Based on this internal rate of return $i_{j,t}$, we calculate the asset-specific user costs of capital $q_{k,j,t}$ for all tangible and intangible assets:

$$q_{k,j,t} = p^I_{k,j,t-1}i_{j,t} + p^I_{k,j,t}\delta_{k,i} - \left[p^I_{k,j,t} - p^I_{k,j,t-1}\right] \ . \tag{7}$$

The compensation of all assets is derived according to the following relation:

$$CAP_{adj\,k,j,t} = q_{k,j,t}A_{k,j,t} \ . \tag{8}$$

The industry-specific growth rate of new intangible capital services ($Kint$) is calculated as follows:[4]

$$\Delta \ln Kint_{j,t} = \ln Kint_{j,t} - \ln Kint_{j,t-1} = \sum_{k \in INT} \bar{w}^{INT}_{k,j,t} \Delta \ln A_{k,j,t} \tag{9}$$

with $\bar{w}^{INT}_{k,j,t}$ denoting the two-period average share of intangible asset k in total intangible capital compensation:

$$w^{INT}_{k,j,t} = \frac{q_{k,j,t}A_{k,j,t}}{\sum_{k \in INT} q_{k,j,t}A_{k,j,t}} \ . \tag{10}$$

The aggregation of input and output volumes to the total business sector (BS) is based on the Törnquist quantity index described in O'Mahony and Timmer (2009):

$$\Delta \ln Kint_{BS,t} = \bar{\mu}^{INT}_{j,t} \sum_j \Delta \ln Kint_{j,t} \tag{11}$$

with $\bar{\mu}^{INT}_{j,t}$ being the two-period average share of industry j in business sector intangible capital compensation.

3.3 Descriptive Statistics

A first way to evaluate our breakdown of the INTAN-Invest data is to see how the aggregate values of intangible assets are distributed across sectors (Table 3.1). We report descriptive statistics for the 10 out of 14 countries for which we are able to compute growth accounting results: Austria, the

[3] Our numbers for the nominal rate of return including intangibles do not differ substantially from the original EU KLEMS values. Inklaar (2010) displays in table 1 similar effects for the US. We also recalculate the standard EU KLEMS internal rate of return for industries D, G, I as their numbers are based on sub-industries.

[4] Similar calculations are used for ICT and non-ICT capital.

Czech Republic, Denmark, France, Finland, Germany, Italy, the Netherlands, Spain and the UK. In most countries, the largest part of overall intangible investment is concentrated in the manufacturing sector (D). In Germany and Finland, the share exceeds 50 percent. However it is less in the other countries and only 22 percent in the UK. The business service sector ($K71t74$) and wholesale and retail trade (G) exhibit higher shares than the remaining sectors (see Table 3.1). Note that we use the term "intangible investment" for those intangible investments not included in the EU KLEMS data (a major category already included is software).

Looking at industry investment in intangibles relative to value added (Table 3.2) allows us to exclude the effect of industry size. We observe that the share of manufacturing (D) and business services ($K71t74$) remains high. Meanwhile the high share of total intangibles attributed to the wholesale and retail trade industry (G) is close to average when considered relative to value added. All countries except the Czech Republic and Germany display an above average share of intangible investment in manufacturing and business services. In seven countries, financial intermediation J also exhibits a share that exceeds the average.

Table 3.1: Summary Statistics: Share of Industry j in Total Intangible Investment - Mean of Years 1995-2007

Industry	AUT	CZE	DNK	ESP	FIN	FRA	GER	ITA	NLD	UK
AtB	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
C	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
D	0.38	0.29	0.34	0.39	0.60	0.33	0.57	0.35	0.32	0.22
E	0.01	0.02	0.01	0.03	0.02	0.02	0.02	0.01	0.02	0.01
F	0.05	0.08	0.09	0.07	0.03	0.04	0.03	0.05	0.04	0.05
G	0.16	0.15	0.17	0.12	0.08	0.12	0.08	0.21	0.14	0.14
H	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.02	0.02	0.03
I	0.05	0.05	0.06	0.08	0.06	0.06	0.03	0.07	0.09	0.08
J	0.09	0.09	0.07	0.11	0.06	0.10	0.10	0.07	0.09	0.15
K71t74	0.20	0.24	0.19	0.12	0.10	0.27	0.14	0.18	0.22	0.25
O	0.04	0.04	0.04	0.04	0.03	0.03	0.02	0.04	0.04	0.06
BS	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 3.2: Summary Statistics: Share of Intangible Investment in Adjusted Value Added - Mean of Years 1995-2007

Industry	AUT	CZE	DNK	ESP	FIN	FRA	GER	ITA	NLD	UK
AtB	0.01	0.02	0.03	0.01	0.01	0.01	0.03	0.00	0.03	0.04
C	0.04	0.04	0.00	0.04	0.08	0.04	0.07	0.03	0.02	0.02
D	0.09	0.06	0.10	0.07	0.13	0.12	0.12	0.06	0.12	0.11
E	0.03	0.02	0.03	0.04	0.05	0.06	0.04	0.02	0.06	0.05
F	0.03	0.07	0.08	0.03	0.03	0.04	0.03	0.03	0.05	0.07
G	0.06	0.06	0.07	0.04	0.05	0.06	0.04	0.06	0.06	0.09
H	0.02	0.06	0.03	0.01	0.05	0.03	0.03	0.02	0.05	0.07
I	0.04	0.02	0.04	0.03	0.04	0.05	0.03	0.03	0.07	0.09
J	0.08	0.13	0.07	0.07	0.11	0.11	0.10	0.05	0.08	0.17
K71t74	0.11	0.15	0.12	0.06	0.09	0.11	0.06	0.06	0.10	0.15
O	0.05	0.07	0.05	0.04	0.04	0.05	0.03	0.05	0.06	0.10
BS	**0.07**	**0.06**	**0.07**	**0.04**	**0.08**	**0.08**	**0.07**	**0.05**	**0.08**	**0.10**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

4 Growth Accounting

4.1 Method

We use the established growth accounting methodology (see, e.g. Inklaar et al. (2005)) decomposing growth in value added (VA) per worker in industry j in country c at time t into the contributions of inputs per worker and multifactor productivity. We use the value added measure that is augmented by intangible assets. Inputs per worker are ICT capital per worker, non-ICT capital per worker, intangible assets per worker and labor services H divided by the number of workers L, which represents a measure of labor quality (Q). The factor income shares of inputs are represented by $\pi^{c,j,t}_{input}$. In the empirical implementation we use two-period averages to measure them. By definition they sum up to one: $\pi^{ict}_{c,j,t} + \pi^{nict}_{c,j,t} + \pi^{int}_{c,j,t} + \pi^{H}_{c,j,t} = 1$. Growth-accounting then decomposes growth in value added per worker in the following way:

$$\begin{aligned} \Delta \ln \left(\frac{VA}{L}\right)_{c,j,t} &= \pi^{ict}_{c,j,t} \Delta \ln \left(\frac{Kict}{L}\right)_{c,j,t} + \pi^{nict}_{c,j,t} \Delta \ln \left(\frac{Knict}{L}\right)_{c,j,t} + \pi^{int}_{c,j,t} \Delta \ln \left(\frac{Kint}{L}\right)_{c,j,t} \\ &+ \pi^{H}_{c,j,t} \Delta \ln Q_{jit} + \Delta \ln MFP_{c,j,t}. \end{aligned} \tag{12}$$

4.2 Results at the Sectoral Level

We present growth accounting results for 10 out of the 14 EU countries for which we compiled sectoral intangible investment data (Tables 4.7 to 4.8). This restriction comes from the lack of available capital input data in EU KLEMS. Our results of growth accounting for the aggregate business sector are essentially those from the INTAN-Invest data. Slight differences result from using a bottom-up approach in aggregation.

Countries with Low Aggregate Growth in Labor Productivity

Italy and Spain display the lowest average annual growth in labor productivity between 1995 and 2007 among the countries observed, with values below one percent. In Italy, the contribution of intangible assets to labor productivity growth is also the lowest with a value of 0.1 percentage points. A contribution of 0.2 percentage points is observed in Spain but also in Denmark and Germany which grow faster. Looking at sectoral results in Italy, only trade (G) displays a contribution of intangibles above 0.1 percentage points and contributions are even negative in some industries. Compared with other countries, the low contribution in the manufacturing sector (D: 0.1 percentage points) is particularly striking. In Spain, sectoral results are more varied, with manufacturing (D), trade (G) and financial intermediation (J) reaching contributions of intangible capital of 0.3 to 0.4 percentage points. One of the main effects on the low aggregate contribution of intangibles comes from the business services sector ($K71t74$). We represent growth accounting results including intangibles in output and inputs and, for comparison, growth in labor productivity that is not adjusted for intangibles (LP').

Table 4.1: Average Contribution to Labor Productivity Growth - 1995-2007 - ITA

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	2.2	0.0	0.9	0.0	0.2	1.1	2.2
C	0.7	0.0	2.3	-0.1	0.1	-1.6	0.7
D	0.7	0.2	0.5	0.1	0.2	-0.4	0.5
E	2.3	0.1	2.1	0.1	-0.0	0.0	2.3
F	-0.8	0.1	0.5	-0.0	0.1	-1.5	-0.8
G	0.9	0.2	0.8	0.3	0.3	-0.7	0.7
H	-0.6	0.1	0.4	0.1	0.2	-1.4	-0.7
I	2.2	0.2	0.6	0.1	0.1	1.2	2.2
J	2.8	0.7	-0.2	0.1	0.1	1.9	2.8
K71t74	-1.7	0.2	-1.1	-0.0	0.2	-0.9	-1.8
O	-1.1	0.4	0.6	0.1	0.0	-2.2	-1.3
BS	**0.6**	**0.2**	**0.4**	**0.1**	**0.2**	**-0.4**	**0.5**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.2: Average Contribution to Labor Productivity Growth - 1995-2007 - ESP

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	2.5	0.0	1.1	0.1	0.3	1.0	2.5
C	2.1	0.2	0.8	0.4	0.3	0.4	1.4
D	1.2	0.3	0.4	0.4	0.5	-0.4	0.9
E	4.6	0.2	2.7	0.2	0.1	1.4	4.5
F	-1.8	0.1	-0.0	-0.1	0.3	-2.1	-1.8
G	1.2	0.3	0.8	0.3	0.5	-0.7	1.0
H	-1.2	0.1	0.7	0.1	0.3	-2.4	-1.3
I	1.5	1.0	1.2	0.2	0.4	-1.2	1.4
J	5.2	0.9	-0.2	0.3	0.0	4.1	5.4
K71t74	0.4	0.4	0.4	0.0	0.7	-1.2	0.3
O	-0.0	0.6	1.5	0.1	0.4	-2.5	-0.1
BS	**0.8**	**0.3**	**0.4**	**0.2**	**0.5**	**-0.6**	**0.7**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Countries with Medium Aggregate Growth

We consider Denmark (1.3 percent), Germany (1.8 percent), France (2.2 percent), the Netherlands (2.3 percent) and Austria (2.4 percent) as countries with medium growth in labor productivity. In France, the Netherlands and Austria, growth is markedly higher and the contribution of intangibles is also higher with a value of 0.4 percentage points as opposed to 0.2 percentage points in Germany and Denmark. The sectoral structure of the contribution of intangible assets in Germany resembles the one in Spain where only manufacturing (D) and financial intermediation (J) exhibit relatively high values. In Denmark these are also the sectors with the highest contributions (0.5 percentage points in manufacturing, 0.4 percentage points in financial intermediation) but a few more sectors than in Germany exhibit contributions of 0.2 percentage points. German growth is largely driven by the accumulation of non-ICT tangible capital and ICT. In Austria, France and the Netherlands the contribution of intangibles to labor productivity growth is 0.7 percentage points in manufacturing (D), which exceeds the values of countries with lower growth. In France, financial intermediation also exhibits a strong contribution of 0.8 percentage points. In the Netherlands, the contribution of intangibles is somewhat more evenly distributed across sectors with transport (I), financial intermediation

(J) and business services ($K71t74$) exhibiting contributions of 0.4 percentage points or more.

Table 4.3: Average Contribution to Labor Productivity Growth - 1995-2007 - DNK

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	-0.3	0.3	0.6	0.1	-0.3	-1.0	-0.5
C	5.5	0.7	4.3	0.0	0.0	0.4	5.5
D	2.4	0.6	0.5	0.5	0.3	0.4	2.1
E	1.8	0.5	3.5	0.2	0.0	-2.3	1.6
F	0.1	0.1	0.0	0.0	-0.1	0.0	0.1
G	1.6	0.7	-0.1	0.2	-0.1	0.8	1.5
H	-3.3	0.3	0.0	-0.0	0.2	-3.8	-3.4
I	2.8	0.9	0.7	0.1	-0.0	1.0	2.7
J	5.0	2.4	-1.2	0.4	0.5	2.9	5.2
K71t74	-0.8	1.3	0.1	0.2	0.1	-2.3	-1.3
O	-1.0	1.1	0.4	0.2	0.0	-2.7	-1.3
BS	**1.3**	**0.9**	**0.1**	**0.2**	**0.1**	**-0.1**	**1.1**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.4: Average Contribution to Labor Productivity Growth - 1995-2007 - GER

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	4.0	0.1	-0.4	0.2	-0.4	4.6	3.8
C	0.9	0.1	0.1	0.1	0.2	0.5	1.0
D	3.2	0.2	0.3	0.5	0.2	2.0	3.1
E	4.4	0.3	2.2	0.2	0.1	1.6	4.4
F	-0.1	0.1	0.0	0.1	0.2	-0.4	-0.1
G	1.9	0.3	0.2	0.0	-0.1	1.4	2.0
H	0.1	0.1	-0.0	-0.0	-0.0	0.1	0.1
I	4.0	0.4	0.9	0.1	-0.2	2.7	4.0
J	1.5	0.6	0.2	0.5	0.1	0.2	1.3
K71t74	-1.5	1.1	0.4	0.1	-0.1	-3.0	-1.7
O	-0.7	0.2	-0.1	0.0	-0.2	-0.6	-0.7
BS	**1.8**	**0.5**	**0.5**	**0.2**	**-0.0**	**0.6**	**1.7**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.5: Average Contribution to Labor Productivity Growth - 1995-2007 - FRA

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	2.9	0.0	0.9	0.1	0.6	1.4	2.9
C	-0.0	0.4	1.7	0.2	-0.0	-2.2	-0.1
D	3.7	0.3	0.4	0.7	0.5	1.7	3.5
E	3.8	0.1	0.2	0.1	0.0	3.4	4.0
F	-0.1	0.1	0.2	0.3	0.1	-0.8	-0.3
G	1.5	0.2	0.2	0.3	0.4	0.4	1.3
H	0.5	0.1	0.0	0.2	0.4	-0.1	0.4
I	4.3	0.2	0.5	0.2	0.3	3.0	4.2
J	3.0	0.7	0.7	0.8	0.2	0.6	2.7
K71t74	0.5	0.3	0.4	0.2	0.3	-0.7	0.3
O	1.5	0.2	0.0	0.1	0.2	1.0	1.5
BS	**2.2**	**0.3**	**0.3**	**0.4**	**0.4**	**0.7**	**2.0**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.6: Average Contribution to Labor Productivity Growth - 1995-2007 - NLD

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	1.3	0.1	0.2	0.1	1.1	-0.2	1.2
C	0.9	0.3	2.7	0.2	0.1	-2.4	0.8
D	3.4	0.4	0.3	0.7	0.4	1.6	3.2
E	5.2	0.4	1.5	0.8	0.4	1.9	4.6
F	0.0	0.2	0.1	0.1	0.4	-0.9	-0.1
G	3.8	0.4	0.1	0.3	0.0	2.9	3.8
H	0.6	0.1	0.1	0.2	0.0	0.2	0.5
I	4.8	0.6	0.5	0.4	0.2	3.0	4.7
J	3.1	1.4	-0.6	0.6	0.5	1.0	2.7
K71t74	0.9	0.5	0.2	0.4	0.5	-0.8	0.5
O	0.6	0.4	0.0	0.2	0.3	-0.3	0.5
BS	**2.3**	**0.5**	**0.0**	**0.4**	**0.3**	**1.0**	**2.1**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.7: Average Contribution to Labor Productivity Growth - 1995-2007 - AUT

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	3.8	0.1	0.2	0.0	0.3	3.2	3.8
C	5.4	0.2	0.4	0.2	0.1	4.4	5.5
D	5.0	0.3	0.2	0.7	0.2	3.4	4.9
E	5.1	0.2	0.1	0.2	0.1	4.4	5.1
F	2.7	0.1	0.1	0.3	0.1	2.0	2.5
G	1.4	0.5	-0.2	0.2	0.1	0.8	1.4
H	0.5	0.2	-0.1	0.0	0.1	0.2	0.5
I	2.5	0.4	0.4	0.3	0.1	1.3	2.3
J	1.3	0.8	0.2	0.2	0.3	-0.3	1.2
K71t74	-0.9	0.9	-0.1	0.2	0.0	-1.9	-1.3
O	-1.1	0.3	-0.2	0.1	0.2	-1.5	-1.3
BS	**2.4**	**0.5**	**-0.0**	**0.4**	**0.2**	**1.4**	**2.2**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Countries with High Aggregate Growth

High growth in labor productivity is observed in the UK (2.8 percentage points), Finland (3.6 percentage points) and the Czech Republic (4.0 percentage points). In the Czech Republic, the contribution of intangibles turns out to be low in manufacturing and unusually high in construction. It is also quite high in hotels and restaurants (H), financial intermediation (J) and business services ($K71t74$) compared with other countries. There seems to be little relation between the contribution of intangibles and the growth rate of labor productivity in this country. Particular conditions brought about by transitioning from a centrally planned economy or measurement error may be possible reasons for this. The contribution of intangibles does not exceed the values reached in Austria, France or the Netherlands although overall labor productivity growth is much higher.

The highest values of the aggregate contribution of intangibles to labor productivity growth are observed in the UK with 0.5 percentage points and Finland with 0.6 percentage points. In the UK, the difference in the intangible contribution to other countries results from the values attained in the service sector. The contribution is very high in financial intermediation (J) with 0.9 percentage points and the business services sector ($K71t74$) with 0.6 percentage points. Moreover wholesale and retail trade (G) and hotels and restaurants (H) achieve values that are larger than in other countries. In Finland, the contribution of intangibles to labor productivity growth stands out in the manufacturing sector (D) with a value of 1.1 percentage points. The values in wholesale and retail trade (G: 0.5 percentage points) and business services ($K71t74$: 0.3 percentage points) are also higher than in most other countries.[5]

Table 4.8: Average Contribution to Labor Productivity Growth - 1995-2007 - UK

Industry	**LP**	**ICT**	**NICT**	**INT**	**LAB**	**MFP**	**LP'**
AtB	3.2	0.0	0.7	0.1	0.5	1.9	3.2
C	-0.4	0.0	1.8	0.1	0.0	-2.2	-0.4
D	3.5	0.4	0.3	0.6	0.6	1.5	3.5
E	2.6	0.7	1.0	0.1	0.0	0.7	2.7
F	1.5	0.1	0.4	0.5	0.2	0.3	1.3
G	3.2	0.6	0.7	0.6	0.3	0.9	3.0
H	1.4	0.3	0.7	0.4	0.5	-0.5	1.2
I	4.6	1.5	0.2	0.2	0.2	2.5	4.8
J	4.3	1.1	-0.1	0.9	0.6	1.7	4.2
K71t74	3.4	0.9	0.3	0.6	0.4	1.1	3.4
O	-0.3	0.3	0.5	0.2	0.4	-1.6	-0.5
BS	**2.8**	**0.7**	**0.3**	**0.5**	**0.4**	**0.9**	**2.7**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 4.9: Average Contribution to Labor Productivity Growth - 1995-2007 - FIN

Industry	**LP**	**ICT**	**NICT**	**INT**	**LAB**	**MFP**	**LP'**
AtB	5.0	0.1	0.4	0.1	0.4	4.1	5.0
C	-0.8	0.1	0.9	-0.1	-0.0	-1.6	-0.8
D	6.1	0.3	0.1	1.1	0.2	4.3	6.2
E	5.0	0.4	1.8	0.1	-0.0	2.6	5.2
F	0.7	0.1	0.0	0.3	-0.1	0.4	0.3
G	3.3	0.5	-0.5	0.5	-0.1	3.0	3.0
H	-0.7	0.1	-0.0	0.1	0.2	-1.0	-0.8
I	3.9	0.6	0.1	0.2	-0.0	2.9	3.9
J	2.2	2.2	-1.3	2.1	0.3	-1.1	1.4
K71t74	0.5	0.4	-0.0	0.3	-0.0	-0.2	-0.0
O	-0.3	0.6	-0.5	0.3	0.2	-0.8	-0.6
BS	**3.6**	**0.4**	**-0.2**	**0.6**	**0.2**	**2.5**	**3.4**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

[5] The contribution of intangibles in Finnish financial intermediation (J) of 2.1 percentage points looks questionable and may be related to some problem in the source data.

Table 4.10: Average Contribution to Labor Productivity Growth - 1995-2007 - CZE

Industry	LP	ICT	NICT	INT	LAB	MFP	LP'
AtB	4.7	0.1	2.8	0.2	0.2	1.5	4.6
C	2.6	0.3	2.5	0.4	0.2	-0.9	2.3
D	5.9	0.3	1.7	0.2	0.3	3.3	6.0
E	2.1	0.5	3.0	0.2	0.1	-1.7	1.9
F	0.8	0.2	1.6	1.0	0.2	-2.2	-0.2
G	7.6	0.8	1.4	0.2	0.3	4.8	7.9
H	-6.7	0.1	-0.1	0.6	0.8	-7.9	-7.7
I	3.3	1.3	2.3	0.3	0.1	-0.8	3.0
J	5.5	1.3	0.3	0.7	0.4	2.8	5.5
K71t74	1.0	0.7	0.3	0.5	0.2	-0.7	0.5
O	0.8	0.4	0.7	0.4	0.1	-0.9	0.4
BS	**4.0**	**0.6**	**1.5**	**0.4**	**0.3**	**1.2**	**3.9**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

In most countries manufacturing and, to a slightly lesser extent, financial intermediation have a relatively high contribution of intangibles to labor productivity growth. These industries display a large ratio of intangible investment to value added. The ratio is also high for business services, where we observe a high growth accounting contribution only in the Netherlands and the UK. One reason may be the higher depreciation rate of assets typically accumulated in business services.

Looking at the shares of intangible investment per category (Tables B.1 to B.10) in each industry reveals that the high overall intangible investment and contribution to growth in manufacturing is mainly driven by R&D, which has the lowest depreciation rate. Financial services have a category of intangible investment proper to their industry that accounts for 10 to 30 percent of their total intangible investment and is also assumed to have a comparatively low depreciation rate. High contributions to growth in other sectors show little systematic relation to investment into particular assets. In the UK, we observe a high share of investment in own-account organizational capital in several industries. Since the occupational classification in the UK tends to label more workers as managers than observed in other countries, we cannot completely exclude the possibility of measurement error here, which has to be addressed by future data construction (for alternative measures of own-account organizational capital, see also Squicciarini and Le Mouel (2012)). Business services in the UK also exhibit a higher share of R&D investment than observed in other countries.

5 Econometric Analysis

5.1 Econometric Specification

Growth accounting assesses the contribution of inputs to labor productivity growth under the assumptions of factor payment at marginal productivity and constant returns to scale. In econometric estimations of the production function we assess marginal productivity without tying it to the value of factor shares. There may be several reasons why the output elasticity of a factor deviates from its income share: errors in the measurement of output and inputs, non-constant returns to scale, imperfect competition, or effects of unmeasured complementarities or spillovers (see Stiroh (2002) for a discussion concerning the output elasticity of ICT). While it goes beyond the scope of the present paper to discriminate between these drivers, our results can at least give an indication of whether intangible assets are a plausible candidate for complementarities and spillovers at the industry level. The few papers that previously estimated the coefficient of intangible assets in a production function using aggregate data found surprisingly high values for the output elasticity of intangibles, exceeding the factor share twofold or more (Roth and Thum (2013), Corrado et al. (2013)). We investigate to what extent this result carries over to the industry level.

If the marginal productivities of inputs do not coincide with factor shares, there are no a priori reasons to assume constant returns to scale. Therefore we estimate a sectoral Cobb-Douglas production function for value added with three types of assets and labor services as inputs, allowing for variation in the neutral technology parameter $A_{c,j,t}$ across countries c, industries j and time t as well as for non-constant returns to scale:

$$VA_{c,j,t} = A_{c,j,t} Kict_{c,j,t}^{\beta^{ict}} Knict_{c,j,t}^{\beta^{nict}} Kint_{c,j,t}^{\beta^{int}} H_{c,j,t}^{\beta^{H}}. \tag{13}$$

Taking logs and first differences we obtain the following equation in growth rates:

$$\Delta \ln VA_{c,j,t} = \mu_t + \mu_{c,j} + \beta^{ict} \Delta \ln Kict_{c,j,t} + \beta^{nict} \Delta \ln Knict_{c,j,t} + \beta^{int} \Delta \ln Kint_{c,j,t} + \beta^{H} \Delta \ln H_{c,j,t} + \epsilon_{c,j,t}. \tag{14}$$

Since the equation is written in first differences, country-industry dummies or fixed effects reflect neutral productivity trends that are specific to the single industries in particular countries. Time dummies μ_t allow for a non-constant component in technical change. The coefficients for the different inputs (in logarithms) correspond to their output elasticities. Under constant returns to scale they would sum up to one: $\beta_{ict} + \beta_{nict} + \beta_{int} + \beta_{H} = 1$.

To investigate whether the output elasticity of intangible assets significantly exceeds their factor share, we regress MFP on all inputs as well as time and country-industry effects. Solving equation (12) for MFP growth and replacing growth in value added by the specification of the production function (equation (14)) yields:

$$\begin{aligned} \Delta \ln MFP_{c,j,t} &= \mu_t + \mu_{c,j} + (\beta^{ict} - \pi^{ict}) \Delta \ln Kict_{c,j,t} + (\beta^{nict} - \pi^{nict}) \Delta \ln Knict_{c,j,t} \\ &\quad + (\beta^{int} - \pi^{int}) \Delta \ln Kint_{c,j,t} + (\beta^{H} - \pi^{H}) \Delta \ln H_{c,j,t} + \nu_{c,j,t} \end{aligned} \tag{15}$$

In this equation, we have left out the subscripts for the factor shares which are denoting country, industry and time. The specification has been used previously to estimate potential spillovers from ICT and intangibles (Stiroh (2002), Corrado et al. (2013)). If the regression coefficients of inputs significantly differ from zero, the output elasticities significantly differ from factor shares.

We use four different estimators to estimate the production function and the MFP equation. Differences in productivity levels across countries and industries are eliminated in all specifications since the equations are expressed in first differences. A specification in first differences rather than in levels was chosen in order to estimate roughly the same relationship as is analyzed by the growth accounting method. As a baseline specification we consider a pooled OLS regression. With the least squares dummy variable specification (LSDV) we control for country-specific and industry-specific rates of technical change. In addition, we use fixed-effects (FE) panel regressions with country-industry combinations as panel identifiers. This gives even more weight to growth patterns specific to industries within particular countries. The fourth specification is a system-GMM dynamic panel regression.

With this approach, we aim at controlling for the endogeneity of inputs. It uses second-order (t-2) and third-order lags (t-3) as instruments for all input growth variables and again country-industry combinations as panel identifiers (see, e.g., Dobbelaere and Mairesse (2013)). All regressions are weighted by the average number of hours worked between 1995 and 2007 in countries and industries. When estimating the Cobb-Douglas function, we test for constant returns to scale (CRS).

5.2 Results

We first estimate the production function (14) and the MFP equation (15), testing for deviations of output elasticities from factor shares for the entire sample (Tables 5.1 and 5.2). The coefficient of intangible assets is significant only for the pooled estimation. In the MFP regression some coefficients are negative. This is not surprising since the returns to scale implied by the estimated production function are decreasing. As Stiroh (2005) notes (referring to own results and to Griliches and Mairesse (1998)), low estimates of returns to scale and occasionally insignificant coefficients for capital inputs are typical for panel estimations of production functions.

Since inputs are highly correlated with time, allowing for time-varying technical progress may result in overcontrolling. If progress does not follow any smooth pattern over time, there is a risk that it eliminates a part of the dynamic effects that should be attributed to inputs. Thus we also report estimations without time dummies. Since we estimate equations in first differences, these specifications still allow for neutral factor-augmenting technical change at a constant rate (Tables 5.3 and 5.4). In each table we compare the estimation that includes intangibles in inputs and outputs with the estimation without intangibles.

When dropping time dummies (Table 5.3), the coefficient of intangible assets becomes significant in every specification. With the inclusion of intangible assets, the coefficients for labor decline markedly and the coefficients for ICT decline slightly. In the MFP regressions (Table 5.4) intangible assets now exhibit a significant coefficient in all but one specification. All other inputs do not exhibit positively significant coefficients. If we consider that the fixed effects and the system-GMM specification account best for sectoral heterogeneity, we obtain an output elasticity between 0.12 and 0.18 that exceeds the factor share by about half. While we thus find some indication that the output elasticity of intangible assets exceeds their factor share, the values we observe lie below the values of 0.25 to 0.55 found in previous research using aggregate measures (Roth and Thum (2013), Corrado et al. (2013)).

In the growth accounting results, the contribution of intangibles to labor productivity growth varies notably across sectors. In order to account for sectoral heterogeneity in the econometric analysis, we estimate all specifications with intangibles separately for the goods producing sector (industries C to F, A and B are excluded since they show quite different behavior and have a low contribution of intangibles) and the service sector. The limited number of observations prevents us from estimating production functions for more disaggregated sectors. With this sectoral breakdown the coefficient of intangibles turns significant in most specifications even when including year dummies (Table 5.5). It is higher in the goods producing sector than in the service sector. In the former coefficients range from 0.10 to 0.14. The coefficient of non-ICT is insignificant. In the MFP regressions (Table 5.6) none of the coefficients of the factor inputs turns out to be significantly positive. In the specification without year dummies (Table 5.7) the coefficients of conventional capital are mostly insignificant. Only ICT in the service sector is significantly related to labor productivity growth. The coefficient of intangible investment is now significant in all specifications. We observe little difference between the coefficients in the goods producing and service sectors. The coefficient of intangibles in the MFP regressions is significant in the system-GMM estimations (Table 5.8). Across all specifications, the system-GMM method yields the highest coefficients of intangibles. Assuming that this method correctly accounts for endogeneity, the coefficient of intangibles would amount to $0.18 - 0.20$ and exceed the factor share by $0.11 - 0.13$. The insignificant coefficients of conventional capital should caution against taking these results as more than preliminary evidence. Future work should investigate heterogeneity, complementarity and lagged adjustments in more detail.

The fact that there is little difference in the coefficients of intangibles across sectors is not necessarily at odds with the higher growth accounting contribution observed in manufacturing. The growth accounting contribution depends on both the output elasticity (measured by the factor share) and the increase in intangible assets. If net investment is higher the contribution to growth is higher even at equal output elasticities.

Table 5.1: Dependent Variable: Growth Rate of Value Added

	With Intangibles				**Without Intangibles**			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.064***	0.072***	0.064***	0.095**	0.070***	0.075***	0.065***	0.079*
	(0.023)	(0.022)	(0.024)	(0.040)	(0.024)	(0.022)	(0.025)	(0.042)
Δ ln(N.ICT Cap. Serv.)	0.107**	0.092**	0.082**	0.006	0.112**	0.085**	0.078*	0.040
	(0.048)	(0.041)	(0.041)	(0.092)	(0.050)	(0.040)	(0.041)	(0.095)
Δ ln(Intan. Cap. Serv.)	0.089***	0.042	0.059	0.081				
	(0.033)	(0.034)	(0.036)	(0.056)				
Δ ln(Labor Services)	0.289***	0.308***	0.240***	0.412***	0.316***	0.323***	0.254***	0.528***
	(0.046)	(0.061)	(0.059)	(0.115)	(0.052)	(0.063)	(0.061)	(0.122)
L.Δ ln(Value Added)				-0.041				-0.050
				(0.082)				(0.076)
Constant	0.019***	0.012*	0.021***	0.013***	0.021***	0.014**	0.022***	0.015***
	(0.005)	(0.007)	(0.004)	(0.004)	(0.005)	(0.007)	(0.004)	(0.004)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1320	1320	1320	1210	1320	1320	1320	1210
Adjusted R^2	0.250	0.329	0.178		0.213	0.297	0.147	
CRS	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.012

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.2: Dependent Variable: Growth Rate of MFP

	With Intangibles				Without Intangibles			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.032	0.036	0.029	0.048	0.035	0.036	0.028	0.032
	(0.022)	(0.023)	(0.025)	(0.039)	(0.023)	(0.025)	(0.026)	(0.042)
Δ ln(N.ICT Cap. Serv.)	-0.089**	-0.093**	-0.098**	-0.173*	-0.110**	-0.121***	-0.128**	-0.191**
	(0.043)	(0.042)	(0.045)	(0.093)	(0.044)	(0.044)	(0.049)	(0.095)
Δ ln(Intan. Cap. Serv.)	0.014	-0.026	-0.007	0.003				
	(0.030)	(0.030)	(0.031)	(0.053)				
Δ ln(Labor Services)	-0.411***	-0.382***	-0.444***	-0.294***	-0.432***	-0.410***	-0.475***	-0.250**
	(0.049)	(0.065)	(0.062)	(0.113)	(0.055)	(0.069)	(0.067)	(0.113)
L.Δ ln(MFP)				-0.051				-0.054
				(0.066)				(0.062)
Constant	0.018***	0.019***	0.020***	0.013***	0.020***	0.019***	0.022***	0.015***
	(0.005)	(0.007)	(0.004)	(0.004)	(0.005)	(0.007)	(0.004)	(0.004)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1320	1320	1320	1210	1320	1320	1320	1210
Adjusted R^2	0.174	0.226	0.131		0.179	0.235	0.132	

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.3: Dependent Variable: Growth Rate of Value Added

	With Intangibles				Without Intangibles			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.053***	0.059***	0.054***	0.059***	0.060***	0.063***	0.059***	0.059***
	(0.015)	(0.016)	(0.016)	(0.019)	(0.017)	(0.016)	(0.017)	(0.020)
Δ ln(N.ICT Cap. Serv.)	0.091**	0.088**	0.088**	-0.034	0.106**	0.088**	0.090**	0.007
	(0.045)	(0.036)	(0.042)	(0.102)	(0.048)	(0.036)	(0.042)	(0.097)
Δ ln(Intan. Cap. Serv.)	0.129***	0.092***	0.116***	0.179***				
	(0.033)	(0.031)	(0.031)	(0.053)				
Δ ln(Labor Services)	0.320***	0.364***	0.308***	0.516***	0.359***	0.388***	0.334***	0.650***
	(0.045)	(0.060)	(0.057)	(0.120)	(0.051)	(0.062)	(0.060)	(0.121)
L.Δ ln(Value Added)				-0.066				-0.066
				(0.078)				(0.076)
Constant	0.007**	0.007	0.008***	0.008**	0.010***	0.010	0.011***	0.012***
	(0.003)	(0.006)	(0.002)	(0.003)	(0.003)	(0.006)	(0.002)	(0.004)
N	1320	1320	1320	1210	1320	1320	1320	1210
Adjusted R^2	0.213	0.287	0.118		0.173	0.257	0.087	
CRS	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.052

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.4: Dependent Variable: Growth Rate of MFP

	With Intangibles				Without Intangibles			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.020	0.022	0.018	0.019	0.022	0.022	0.018	0.011
	(0.015)	(0.017)	(0.017)	(0.020)	(0.016)	(0.018)	(0.018)	(0.020)
Δ ln(N.ICT Cap. Serv.)	-0.105**	-0.098**	-0.095*	-0.233**	-0.117***	-0.119***	-0.119**	-0.221**
	(0.041)	(0.039)	(0.049)	(0.096)	(0.043)	(0.042)	(0.055)	(0.089)
Δ ln(Intan. Cap. Serv.)	0.053*	0.022	0.048*	0.104**				
	(0.030)	(0.029)	(0.028)	(0.049)				
Δ ln(Labor Services)	-0.378***	-0.324***	-0.375***	-0.211**	-0.386***	-0.344***	-0.396***	-0.128
	(0.046)	(0.062)	(0.060)	(0.094)	(0.053)	(0.066)	(0.064)	(0.104)
L.Δ ln(MFP)				-0.041				-0.044
				(0.070)				(0.066)
Constant	0.007**	0.014**	0.007***	0.007**	0.010***	0.015**	0.010***	0.012***
	(0.003)	(0.006)	(0.002)	(0.003)	(0.003)	(0.007)	(0.002)	(0.003)
N	1320	1320	1320	1210	1320	1320	1320	1210
Adjusted R^2	0.130	0.178	0.068		0.136	0.192	0.073	

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.5: Dependent Variable: Growth Rate of Value Added Including Intangibles

	Goods Producing Sector				Service Sector			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.087**	0.081**	0.076*	0.088*	0.072**	0.086***	0.089***	0.049
	(0.033)	(0.039)	(0.042)	(0.048)	(0.028)	(0.025)	(0.027)	(0.039)
Δ ln(N.ICT Cap. Serv.)	0.041	0.148	-0.023	-0.011	0.087	0.006	0.050	0.168
	(0.136)	(0.108)	(0.113)	(0.263)	(0.059)	(0.049)	(0.049)	(0.105)
Δ ln(Intan. Cap. Serv.)	0.119***	0.075	0.095**	0.142*	0.098*	0.027	0.075*	0.095
	(0.043)	(0.046)	(0.042)	(0.077)	(0.052)	(0.046)	(0.041)	(0.071)
Δ ln(Labor Services)	0.342***	0.467***	0.406***	0.256	0.190***	0.152**	0.148**	0.186**
	(0.095)	(0.138)	(0.118)	(0.231)	(0.065)	(0.066)	(0.065)	(0.086)
L.Δ ln(Value Added)				0.142				0.193**
				(0.132)				(0.079)
Constant	0.009*	0.011	0.024***	0.007	0.020***	0.003	0.021***	0.012**
	(0.005)	(0.007)	(0.007)	(0.007)	(0.004)	(0.006)	(0.004)	(0.005)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	480	480	480	440	720	720	720	660
Adjusted R^2	0.324	0.422	0.254		0.243	0.380	0.257	
CRS	0.002	0.010	0.000	0.099	0.000	0.000	0.000	0.000

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.6: Dependent Variable: Growth Rate of MFP Including Intangibles

	Goods Producing Sector				Service Sector			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.067**	0.059	0.056	0.093***	0.023	0.035	0.039	0.020
	(0.033)	(0.040)	(0.045)	(0.036)	(0.026)	(0.027)	(0.029)	(0.037)
Δ ln(N.ICT Cap. Serv.)	-0.154	-0.039	-0.227**	-0.156	-0.108*	-0.188***	-0.140***	0.079
	(0.117)	(0.099)	(0.105)	(0.238)	(0.054)	(0.050)	(0.046)	(0.107)
Δ ln(Intan. Cap. Serv.)	0.047	0.009	0.025	0.057	0.014	-0.050	0.006	0.056
	(0.036)	(0.037)	(0.033)	(0.066)	(0.048)	(0.045)	(0.040)	(0.088)
Δ ln(Labor Services)	-0.323***	-0.206	-0.254**	-0.455**	-0.489***	-0.526***	-0.525***	-0.369***
	(0.103)	(0.144)	(0.125)	(0.223)	(0.068)	(0.073)	(0.071)	(0.141)
L.Δ ln(MFP)				0.058				0.137*
				(0.101)				(0.080)
Constant	0.007	0.012*	0.021***	0.006	0.020***	0.009	0.021***	0.008
	(0.005)	(0.007)	(0.008)	(0.005)	(0.004)	(0.006)	(0.004)	(0.006)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	480	480	480	440	720	720	720	660
Adjusted R^2	0.180	0.268	0.152		0.225	0.316	0.197	

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.7: Dependent Variable: Growth Rate of Value Added Including Intangibles

	Goods Producing Sector				Service Sector			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.033	0.020	0.020	0.041	0.074***	0.091***	0.085***	0.046**
	(0.028)	(0.033)	(0.029)	(0.033)	(0.020)	(0.018)	(0.020)	(0.021)
Δ ln(N.ICT Cap. Serv.)	0.029	0.133	-0.047	-0.075	0.079	0.022	0.073	0.064
	(0.123)	(0.087)	(0.109)	(0.108)	(0.057)	(0.048)	(0.047)	(0.085)
Δ ln(Intan. Cap. Serv.)	0.152***	0.106**	0.130***	0.183***	0.141***	0.089*	0.139***	0.200***
	(0.045)	(0.040)	(0.040)	(0.052)	(0.052)	(0.048)	(0.043)	(0.075)
Δ ln(Labor Services)	0.415***	0.536***	0.467***	0.359***	0.214***	0.220***	0.215***	0.266***
	(0.082)	(0.126)	(0.110)	(0.103)	(0.060)	(0.068)	(0.066)	(0.077)
L.Δ ln(Value Added)				0.113				0.157**
				(0.075)				(0.065)
Constant	0.007	0.014**	0.010***	0.007	0.009***	-0.010**	0.008***	0.004
	(0.006)	(0.006)	(0.004)	(0.005)	(0.003)	(0.005)	(0.002)	(0.003)
N	480	480	480	440	720	720	720	660
Adjusted R^2	0.256	0.349	0.159		0.201	0.323	0.186	
CRS	0.004	0.049	0.002	0.000	0.000	0.000	0.000	0.000

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table 5.8: Dependent Variable: Growth Rate of MFP Including Intangibles

	Goods Producing Sector				Service Sector			
	(1) POLS	(2) LSDV	(3) FE	(4) SGMM	(5) POLS	(6) LSDV	(7) FE	(8) SGMM
Δ ln(ICT Cap. Serv.)	0.011	-0.004	-0.002	0.022	0.028	0.043**	0.036	-0.002
	(0.028)	(0.034)	(0.030)	(0.035)	(0.019)	(0.020)	(0.022)	(0.027)
Δ ln(N.ICT Cap. Serv.)	-0.164	-0.052	-0.251**	-0.217	-0.116**	-0.171***	-0.118**	-0.022
	(0.111)	(0.084)	(0.108)	(0.145)	(0.053)	(0.050)	(0.045)	(0.085)
Δ ln(Intan. Cap. Serv.)	0.077*	0.038	0.056	0.122**	0.058	0.012	0.069	0.146**
	(0.040)	(0.034)	(0.035)	(0.049)	(0.050)	(0.048)	(0.043)	(0.073)
Δ ln(Labor Services)	-0.251***	-0.141	-0.198*	-0.328***	-0.465***	-0.455***	-0.457***	-0.397***
	(0.090)	(0.132)	(0.115)	(0.105)	(0.062)	(0.072)	(0.070)	(0.094)
L.Δ ln(MFP)				0.082				0.173***
				(0.081)				(0.055)
Constant	0.006	0.016**	0.009**	0.005	0.009***	-0.005	0.007***	0.004
	(0.006)	(0.006)	(0.004)	(0.005)	(0.003)	(0.005)	(0.003)	(0.003)
N	480	480	480	440	720	720	720	660
Adjusted R^2	0.100	0.183	0.053		0.174	0.251	0.120	

Clustered standard errors by country-industry combination in parentheses, * p<0.10, ** p<0.05, *** p<0.01.
Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

6 Conclusion

In this paper we have investigated the importance of investment in intangible assets for labor productivity growth at the sectoral level based on the construction of a sectoral breakdown of the INTAN-Invest data. In growth accounting for 10 EU countries we find the contribution of intangibles to labor productivity growth to be higher in manufacturing than in services. This is in line with results found by Chun et al. (2012) for Japan. The high contribution of manufacturing is associated with a high share of intangible investment in value added in this sector. A large part of its intangible investment falls into the category R&D. In addition to the investment being higher, the assumed low depreciation rate of R&D capital may have an effect on the high contribution of intangibles to productivity growth in manufacturing. Meanwhile services are responsible for the high contribution of intangibles observed in the UK. The UK exhibits higher shares of intangible investment in value added in business services and financial intermediation than other countries.

Our results partly confirm evidence from previous studies using intangible measures at the country level or partial measures of intangibles at the sectoral level, which suggests that the output elasticity of intangibles exceeds its factor share. With values between 0.10 and 0.20, we find that the output elasticity of intangibles is, however, lower than the values of $0.25 - 0.55$ found with country-level measures in Roth and Thum (2013) and Corrado et al. (2013). In some specifications we do not find any significant difference between the output share of intangibles and their factor income share.

We expect that future research and data construction efforts will refine the methodology of measuring intangibles at the sectoral level. This may include building up estimates from national accounts and micro data and developing better methodologies to measure prices and service lives. An important challenge will be to find out whether the result that manufacturing industries have a higher contribution of intangibles to growth remains robust, or whether the assets typically used in service industries are currently just harder to capture. On the analytical side, future research should revisit the issue of spillovers and complementarities of intangible assets using sectoral data.

Appendix

A Coverage of Assets, Industries and Countries

Table A.1: Industry Coverage

NACE rev. 1.1	Description
	Goods Producing Sector
AtB	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
D	Total Manufacturing
E	Electricity, Gas and Water Supply
F	Construction
	Service Sector
G	Wholesale and Retail Trade
H	Hotels and Restaurants
I	Transport and Storage and Communication
J	Financial Intermediation
K71t74	Renting of Machinery and Equipment and Other Business Activities
O	Other Community, Social and Personal Services

Table A.2: Country Coverage

Country Code	Country
AUT	Austria
CZE	Czech Republic
DNK	Denmark
ESP	Spain
FIN	Finland
FRA	France
GER	Germany
ITA	Italy
NLD	Netherlands
UK	United Kingdom

Measures of intangibles assets at the industry level are also constructed for Belgium, Hungary, Ireland and Sweden for which complete growth accounting data are not available.

Table A.3: List of Assets

Acronym	Description	Depreciation Rate
INT	**New intangibles**	
R&D	Scientific Research and Development	.150
FSHK	Firm-Specific Human Capital	.400
NFP	New Product Development Costs in the Financial Industry	.200
Arch	New Architectural and Engineering Designs	.200
MKTR	Market Research	.550
ADV	Advertising Expenditure	.550
OKo	Own-Account Development of Organizational Structures	.400
OKp	Purchased Organizational Structures	.400
ICT	**ICT assets**	
IT	Computing Equipment	
CT	Communications Equipment	
Soft	Software	
NonICT	**Non-ICT assets**	
TraEq	Transport Equipment	
OMach	Other Machinery and Equipment	
OCon	Total Non-Residential Investment	
RStruc	Residential Structures	
Other	Other Assets	

Note: Depreciation rates for new intangible assets are taken from Corrado et al. (2012, page 25).
"New" intangibles are those not yet included in national accounts. ICT and Non-ICT assets are those covered by national accounts data in the EU KLEMS database.

B Intangible Assets at Sectoral Level: Data Constructed in the INDICSER Project

B.1 Investment in Own-Account Development of Organizational Structures (OKo)

The primary data sources for calculating own-account organizational capital are occupation data from the harmonized EU Labor Force Surveys (EU LFS) and wage rates from the EU Structure of Earnings Survey (EU SES) and the Survey of Income and Living Conditions (EU SILC). For Germany, additional data on occupational shares from the Mikrozensus are used as the EU LFS series are only available from 2002. Annual estimates of own-account intangible capital were calculated from 1995 to 2007. The process for calculating own-account organizational capital for business sectors ($A-K$ and O) was as follows:

1. Extract data from EU LFS on employees by 3-digit occupation group and skill level. The relevant occupation groups according to the ISCO88 classification are:

    - 121 Directors and Chief Executives
    - 122 Production and Operations Department Managers
    - 123 Other Department Managers
    - 131 General Managers.

Note 123 includes R&D managers but there is insufficient information in the LFS to exclude these. The skill levels are High (ISCED 5,6), Intermediate (ISCED 3,4) and Low (ISCED 1,2).

2. Calculate expenditure on own-account organizational investment by multiplying the employment shares of each occupation group by their earnings. For each industry and time period earnings by skill level were applied to each occupation group using data from EU KLEMS. An additional adjustment, common to all years, to take account of the generally higher wages of managers for all skill levels by industry was based on earnings data from EU SES and EU SILC. The small sample sizes in these surveys precluded estimating earnings of managers annually.
3. Calculate investment by multiplying the expenditures by a constant factor x (assumed to be 20% in INNODRIVE estimates).
4. Calculate the share of investment by industry in total business sector investment.
5. Apply these shares to own-account organizational investments from INNODRIVE (The aggregate values of organizational investment correspond to those in INTAN-Invest. INNODRIVE contains additional information on the own-account and the purchased component.).

Note, in practice step 3 is not necessary if the investment factor is assumed to be the same across industries.

B.2 Investment in Firm-Specific Human Capital (FSHK)

These estimates were derived from training propensities and duration of training from the EU LFS, with direct costs of training courses estimated from the Eurostat Continuous Vocational Training Surveys and opportunity costs based on average earnings by skill group from EU KLEMS. For details of the calculations see O'Mahony (2012).

B.3 New Product Development Costs in the Financial Industry (NFP)

New product development costs in the financial industry only occur in NACE rev. 1.1 industry J and therefore equal business sector investment of INTAN-Invest. Value added in this sector is augmented by investment in new product development.

B.4 Scientific R&D (R&D)

The main source for the sectoral R&D estimates is the OECD ANBERD (Analytical Business Enterprise Research and Development) database (OECD (2011)). We use the variable R&D expenditures by main activity. For Denmark, France, Sweden and the United Kingdom we use the OECD BERD database (OECD (2012)). Due to a lack of data, the industry shares in business sector R&D are the same for the whole period 1995-2007 in France and the UK. We replace missing values by imputation and extrapolation techniques provided in the statistical software STATA. Imputation and extrapolation is based on nominal value added by industry taken from EU KLEMS. Neither of the OECD databases provides proper information for industries $K71t74$ and O, as observations are only available for total K and LtQ. As an ad-hoc solution we use the value for total K for $K71t74$ and a fixed percentage share of the value for industries LtQ for O.[6] To avoid double counting issues with software and NFP, we subtract industries $K72$ (computer and related activities) and J (financial intermediation) from our R&D estimates as in INTAN-Invest. As with organizational capital, we calculate industry shares and use INTAN-Invest totals as controls. Industry $K71t74$ includes $K73$ (research and development) which provides research activities for firms situated in other industries of the business sector. A considerable amount of R&D intangibles in $K73$ thus ought to be counted as purchased and not as own-account intangible R&D capital. Therefore, not all R&D expenditures in $K73$ should, in principle, be treated as R&D intangibles for $K71t74$. While the data currently available, there does not seem to be any satisfactory solution[7]

B.5 Investment in Purchased Organizational Structures (OKp), New Architectural and Engineering Designs (Arch), Market Research (MKTR) and Advertising Expenditure (ADV)

Our sectoral estimates for purchased intangible investments (OKp, Arch, MKTR and ADV) are based on use tables at purchasers' prices from the World Input-Output Database (WIOD) described by Timmer (2012). Investments for each of the four purchased intangible assets k in industry j at time t are calculated as follows:

$$I_{k,j,t} = I_{k,BS,t} * \text{use share of industry } j \text{ in CPA 2002 K74} \tag{16}$$

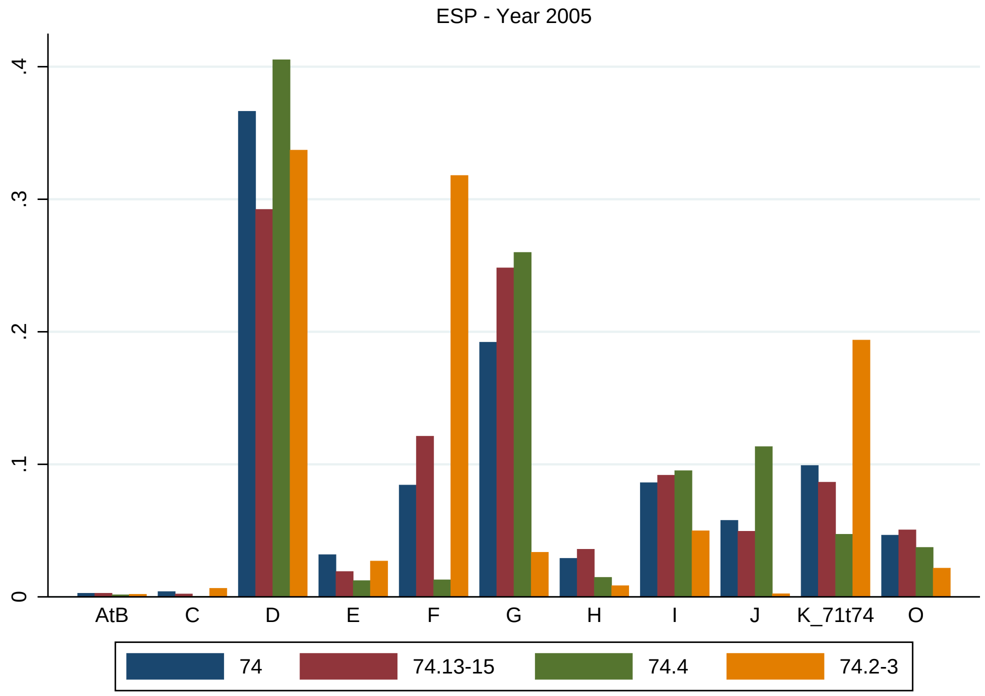
with $I_{k,BS,t}$ being the total business sector (BS) intangible investment taken from INTAN-Invest. We would prefer to have more detailed use tables incorporating data for $K74.13$ (MKTR), $K74.14$ (OKp), $K74.2$ (Arch) and $K74.4$ (ADV). They are currently only available for the UK and Spain in NACE rev. 1.1. Detailed data based on NACE rev. 2 are only available for the year 2008. Figures B.1 and B.2 compare the WIOD-based shares with the more detailed ones of the national statistical offices of Spain and the United Kingdom. The amount of error induced by using the same WIOD-based $K74$ shares for OKp, Arch, MKTR and ADV is often rather small. The biggest difference occurs for Arch in industry F. The figures B.3 and B.4 show the evolution of the $K74$ shares in WIOD over time. In the UK, we discover a clear upward trend of the use share of $K74$ in its own industry $K71t74$. We therefore prefer the WIOD-based approach over using the more detailed shares based on NACE rev. 2, which are available only for the year 2008.

Sectoral value added is increased by expenditures for these purchased services now counted as investment.

[6] Based on the NACE rev. 2 numbers for $L68$ (real estate activities), the impact of including the corresponding NACE rev. 1.1 $K70$ in our $K71t74$ estimates is negligible. Furthermore, we define the percentage share of O in LtQ as 0.2 for all countries.

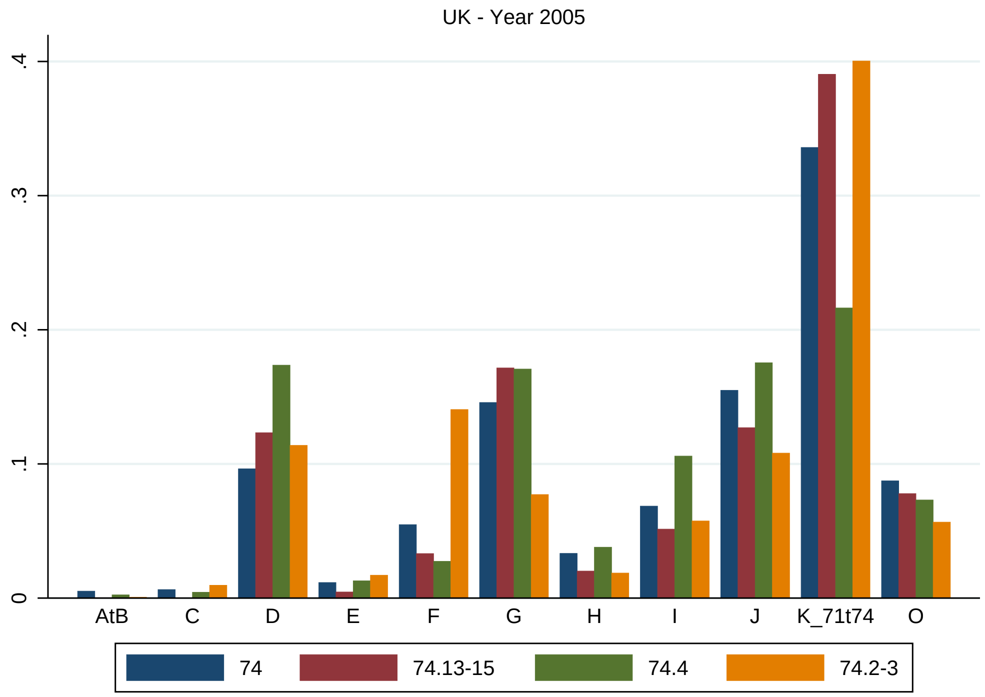
[7] As an ad-hoc solution, one could probably use the business sector industry shares in R&D expenditures to split up $K73$. Another potential source of error in our estimates of intangible R&D capital is the treatment of the public sector. Especially the higher education sector $M80.3$ is a potential supplier of additional intangible R&D investment in the business sector.

Figure B.1: Use Shares of Industries j of CPA 2002 74, 74.4, 74.2-3 and 74.13-15



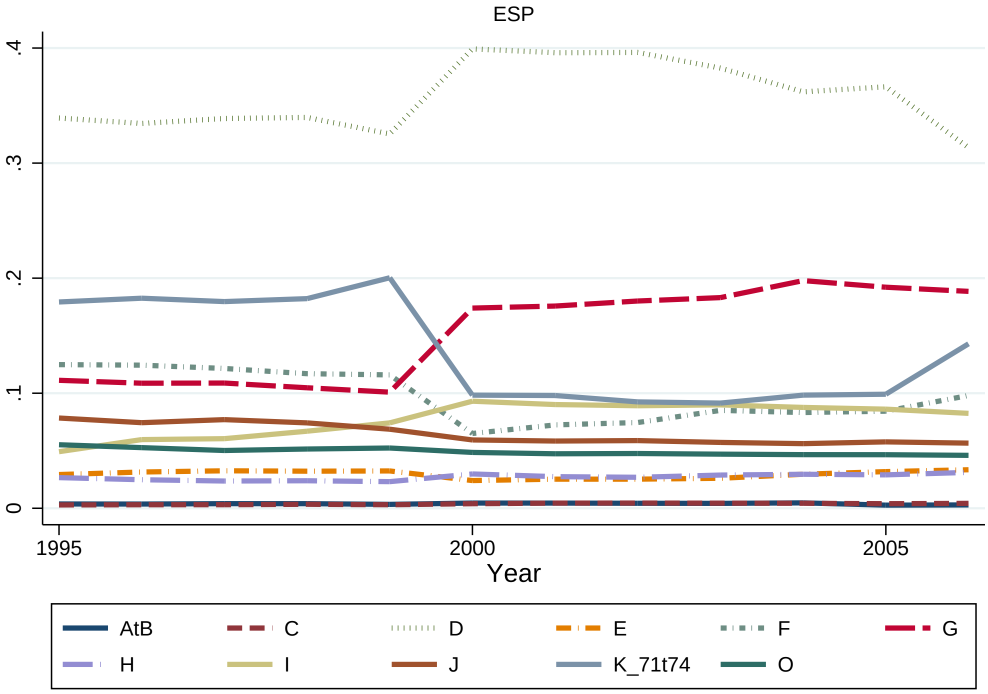
Source: WIOD and INE - own calculations.

Figure B.2: Use Shares of Industries j of CPA 2002 74, 74.4, 74.2-3 and 74.13-15



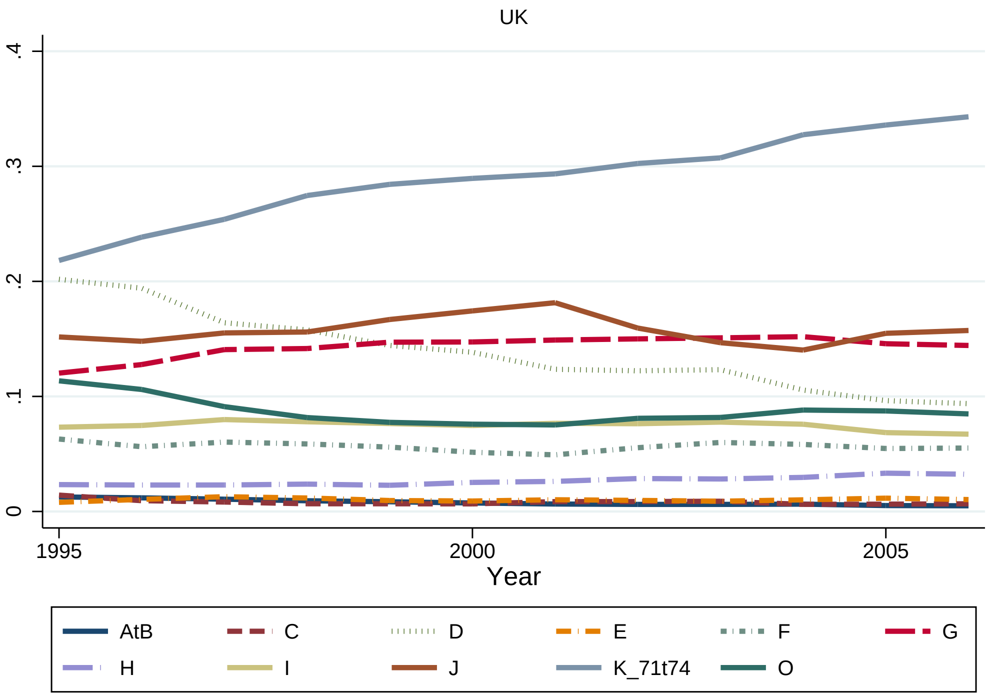
Source: WIOD and ONS - own calculations.

Figure B.3: Use Shares of Industries j of CPA 2002 74 - ESP



Source: WIOD - own calculations.

Figure B.4: Use Shares of Industries j of CPA 2002 74 - UK



Source: WIOD - own calculations.

B.6 Shares per Asset Type in Industry Intangible Investment

Tables B.1 to B.10 show total industry investment in intangibles split up into the shares of the 8 categories.

Table B.1: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - AUT - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.39	0.11	0.08	0.02	0.16	0.00	0.17	0.07	1.00
C	0.10	0.14	0.03	0.03	0.18	0.00	0.19	0.33	1.00
D	0.14	0.06	0.06	0.01	0.09	0.00	0.09	0.55	1.00
E	0.25	0.10	0.28	0.02	0.14	0.00	0.14	0.08	1.00
F	0.16	0.15	0.17	0.03	0.22	0.00	0.23	0.03	1.00
G	0.44	0.10	0.08	0.02	0.14	0.00	0.15	0.06	1.00
H	0.42	0.12	0.07	0.02	0.17	0.00	0.18	0.00	1.00
I	0.23	0.12	0.21	0.02	0.17	0.00	0.18	0.07	1.00
J	0.29	0.10	0.20	0.02	0.14	0.12	0.14	0.00	1.00
K71t74	0.12	0.15	0.05	0.03	0.21	0.00	0.22	0.23	1.00
O	0.25	0.15	0.13	0.03	0.21	0.00	0.22	0.01	1.00
BS	**0.22**	**0.10**	**0.09**	**0.02**	**0.14**	**0.01**	**0.15**	**0.27**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.2: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - CZE - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.40	0.12	0.05	0.05	0.12	0.00	0.17	0.09	1.00
C	0.18	0.19	0.04	0.07	0.18	0.00	0.26	0.08	1.00
D	0.13	0.13	0.02	0.05	0.12	0.00	0.18	0.37	1.00
E	0.24	0.18	0.08	0.07	0.17	0.00	0.25	0.01	1.00
F	0.15	0.22	0.01	0.08	0.21	0.00	0.31	0.03	1.00
G	0.14	0.22	0.01	0.08	0.21	0.00	0.32	0.02	1.00
H	0.17	0.22	0.00	0.08	0.21	0.00	0.31	0.00	1.00
I	0.20	0.20	0.04	0.07	0.19	0.00	0.28	0.02	1.00
J	0.13	0.19	0.03	0.07	0.18	0.13	0.27	0.00	1.00
K71t74	0.04	0.22	0.02	0.08	0.21	0.00	0.31	0.12	1.00
O	0.11	0.23	0.02	0.08	0.22	0.00	0.33	0.02	1.00
BS	**0.12**	**0.19**	**0.02**	**0.07**	**0.18**	**0.01**	**0.27**	**0.14**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.3: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - DNK - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.04	0.18	0.11	0.06	0.26	0.00	0.32	0.03	1.00
C	0.11	0.13	0.27	0.05	0.19	0.00	0.24	0.01	1.00
D	0.08	0.05	0.16	0.02	0.08	0.00	0.09	0.52	1.00
E	0.08	0.08	0.44	0.03	0.12	0.00	0.15	0.09	1.00
F	0.03	0.19	0.11	0.07	0.27	0.00	0.33	0.00	1.00
G	0.22	0.11	0.15	0.04	0.15	0.00	0.19	0.15	1.00
H	0.18	0.14	0.16	0.05	0.20	0.00	0.25	0.02	1.00
I	0.13	0.10	0.28	0.04	0.15	0.00	0.19	0.12	1.00
J	0.20	0.07	0.31	0.02	0.10	0.19	0.12	0.00	1.00
K71t74	0.09	0.10	0.14	0.04	0.15	0.00	0.18	0.30	1.00
O	0.10	0.15	0.22	0.05	0.21	0.00	0.26	0.00	1.00
BS	**0.11**	**0.10**	**0.17**	**0.03**	**0.14**	**0.01**	**0.17**	**0.27**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.4: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - ESP - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.17	0.04	0.13	0.04	0.11	0.00	0.11	0.40	1.00
C	0.18	0.08	0.08	0.08	0.20	0.00	0.19	0.19	1.00
D	0.11	0.08	0.07	0.07	0.18	0.00	0.18	0.31	1.00
E	0.11	0.10	0.09	0.09	0.24	0.00	0.24	0.13	1.00
F	0.08	0.11	0.14	0.10	0.27	0.00	0.26	0.04	1.00
G	0.17	0.11	0.09	0.10	0.26	0.00	0.26	0.02	1.00
H	0.14	0.09	0.23	0.09	0.22	0.00	0.22	0.01	1.00
I	0.14	0.09	0.12	0.08	0.21	0.00	0.21	0.16	1.00
J	0.25	0.05	0.11	0.05	0.12	0.32	0.12	0.00	1.00
K71t74	0.13	0.09	0.13	0.09	0.23	0.00	0.23	0.09	1.00
O	0.13	0.10	0.16	0.10	0.25	0.00	0.24	0.02	1.00
BS	**0.14**	**0.08**	**0.10**	**0.08**	**0.20**	**0.04**	**0.20**	**0.16**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.5: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - FIN - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.23	0.10	0.32	0.03	0.14	0.00	0.15	0.04	1.00
C	0.18	0.13	0.09	0.03	0.18	0.00	0.20	0.18	1.00
D	0.08	0.08	0.07	0.02	0.11	0.00	0.12	0.52	1.00
E	0.13	0.12	0.22	0.03	0.17	0.00	0.18	0.14	1.00
F	0.12	0.14	0.19	0.04	0.19	0.00	0.21	0.12	1.00
G	0.29	0.10	0.21	0.03	0.14	0.00	0.15	0.08	1.00
H	0.26	0.14	0.17	0.04	0.19	0.00	0.20	0.00	1.00
I	0.19	0.11	0.17	0.03	0.15	0.00	0.17	0.19	1.00
J	0.48	0.02	0.20	0.01	0.03	0.23	0.03	0.00	1.00
K71t74	0.19	0.08	0.19	0.02	0.11	0.00	0.12	0.29	1.00
O	0.19	0.10	0.38	0.03	0.14	0.00	0.15	0.02	1.00
BS	**0.14**	**0.09**	**0.12**	**0.02**	**0.12**	**0.01**	**0.13**	**0.36**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.6: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - FRA - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.06	0.24	0.16	0.07	0.12	0.00	0.21	0.15	1.00
C	0.23	0.15	0.33	0.05	0.08	0.00	0.13	0.04	1.00
D	0.07	0.14	0.09	0.04	0.07	0.00	0.13	0.45	1.00
E	0.07	0.20	0.20	0.06	0.10	0.00	0.18	0.20	1.00
F	0.06	0.29	0.12	0.09	0.14	0.00	0.27	0.03	1.00
G	0.24	0.24	0.08	0.07	0.12	0.00	0.22	0.05	1.00
H	0.19	0.24	0.17	0.07	0.12	0.00	0.22	0.00	1.00
I	0.16	0.21	0.13	0.06	0.10	0.00	0.19	0.15	1.00
J	0.31	0.15	0.10	0.04	0.07	0.19	0.13	0.00	1.00
K71t74	0.10	0.21	0.07	0.06	0.10	0.00	0.19	0.26	1.00
O	0.19	0.24	0.17	0.07	0.12	0.00	0.21	0.01	1.00
BS	**0.13**	**0.19**	**0.09**	**0.06**	**0.09**	**0.02**	**0.17**	**0.24**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.7: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - GER - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.10	0.22	0.06	0.06	0.20	0.00	0.25	0.10	1.00
C	0.12	0.21	0.07	0.06	0.20	0.00	0.24	0.12	1.00
D	0.07	0.10	0.04	0.03	0.10	0.00	0.12	0.55	1.00
E	0.10	0.19	0.19	0.06	0.19	0.00	0.22	0.06	1.00
F	0.12	0.21	0.13	0.06	0.20	0.00	0.25	0.02	1.00
G	0.34	0.16	0.11	0.05	0.15	0.00	0.18	0.01	1.00
H	0.40	0.15	0.10	0.04	0.14	0.00	0.17	0.00	1.00
I	0.16	0.16	0.18	0.05	0.15	0.00	0.18	0.12	1.00
J	0.08	0.20	0.10	0.06	0.19	0.15	0.23	0.00	1.00
K71t74	0.07	0.22	0.09	0.06	0.21	0.00	0.26	0.09	1.00
O	0.17	0.20	0.16	0.06	0.19	0.00	0.23	0.00	1.00
BS	**0.10**	**0.14**	**0.07**	**0.04**	**0.14**	**0.01**	**0.16**	**0.33**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.8: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - ITA - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.40	0.15	0.04	0.11	0.12	0.00	0.17	0.00	1.00
C	0.26	0.13	0.03	0.09	0.10	0.00	0.14	0.26	1.00
D	0.11	0.14	0.02	0.10	0.11	0.00	0.15	0.37	1.00
E	0.15	0.15	0.13	0.11	0.11	0.00	0.16	0.20	1.00
F	0.07	0.25	0.02	0.19	0.19	0.00	0.28	0.01	1.00
G	0.08	0.25	0.00	0.18	0.19	0.00	0.27	0.01	1.00
H	0.12	0.24	0.01	0.18	0.19	0.00	0.27	0.00	1.00
I	0.09	0.23	0.02	0.17	0.18	0.00	0.26	0.04	1.00
J	0.49	0.06	0.06	0.04	0.04	0.25	0.06	0.00	1.00
K71t74	0.05	0.23	0.02	0.17	0.18	0.00	0.25	0.12	1.00
O	0.16	0.23	0.02	0.17	0.18	0.00	0.25	0.00	1.00
BS	**0.12**	**0.19**	**0.02**	**0.14**	**0.15**	**0.02**	**0.21**	**0.16**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.9: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - NLD - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.16	0.22	0.05	0.10	0.13	0.00	0.17	0.16	1.00
C	0.09	0.14	0.07	0.07	0.09	0.00	0.11	0.43	1.00
D	0.11	0.14	0.05	0.07	0.08	0.00	0.11	0.44	1.00
E	0.17	0.25	0.08	0.12	0.14	0.00	0.19	0.05	1.00
F	0.28	0.19	0.13	0.09	0.12	0.00	0.15	0.04	1.00
G	0.23	0.22	0.08	0.11	0.13	0.00	0.17	0.06	1.00
H	0.31	0.22	0.07	0.10	0.13	0.00	0.17	0.00	1.00
I	0.12	0.26	0.10	0.12	0.16	0.00	0.20	0.04	1.00
J	0.16	0.15	0.17	0.07	0.09	0.24	0.12	0.00	1.00
K71t74	0.12	0.24	0.12	0.12	0.15	0.00	0.19	0.05	1.00
O	0.17	0.25	0.11	0.12	0.15	0.00	0.20	0.00	1.00
BS	**0.15**	**0.20**	**0.09**	**0.09**	**0.12**	**0.02**	**0.15**	**0.17**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

Table B.10: Summary Statistics: Share of Intangible Asset k in Total Intangible Investment - UK - Mean of Years 1995-2007

Industry	OKo	OKp	FSHK	MKTR	ADV	NFP	Arch	R&D	INT
AtB	0.31	0.19	0.09	0.07	0.15	0.00	0.18	0.02	1.00
C	0.21	0.15	0.24	0.05	0.11	0.00	0.14	0.09	1.00
D	0.28	0.08	0.20	0.03	0.06	0.00	0.07	0.28	1.00
E	0.25	0.11	0.40	0.04	0.08	0.00	0.10	0.02	1.00
F	0.30	0.14	0.25	0.05	0.11	0.00	0.14	0.01	1.00
G	0.36	0.14	0.19	0.05	0.10	0.00	0.13	0.04	1.00
H	0.36	0.14	0.21	0.05	0.11	0.00	0.13	0.00	1.00
I	0.23	0.12	0.25	0.04	0.09	0.00	0.11	0.16	1.00
J	0.29	0.14	0.16	0.05	0.11	0.11	0.13	0.00	1.00
K71t74	0.18	0.15	0.15	0.05	0.11	0.00	0.14	0.21	1.00
O	0.18	0.19	0.22	0.07	0.15	0.00	0.18	0.01	1.00
BS	**0.26**	**0.13**	**0.19**	**0.04**	**0.10**	**0.02**	**0.12**	**0.14**	**1.00**

Source: EU KLEMS Release 2009, INTAN-Invest and INDICSER - own calculations.

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