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INTANGIBLE CAPITAL AND LABOR PRODUCTIVITY GROWTH: PANEL EVIDENCE FOR THE EU FROM 1998–2005

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Using new international comparable data on intangible capital investment by business within a panel analysis between 1998 and 2005 in an EU country sample, a positive and significant relationship between intangible capital investment and labor productivity growth is detected. This relationship proves to be robust to a range of alterations. The empirical analysis confirms previous findings that the inclusion of business intangible capital investment in the asset boundary of the national accounting framework increases the rate of change of output per hour worked more rapidly. In addition, intangible capital is able to explain a significant portion of the unexplained international variance in labor productivity growth, and becomes a dominant source of growth.

JEL Codes: C23, O47, O52

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1. INTRODUCTION

As highly developed economies transform more and more into knowledge economies, the input of intangible capital has become vital for the future competitiveness of their economies (Corrado *et al.*, 2005; World Bank, 2006), as well as the competitiveness of their firms (Teece, 1998, p. 76; Eustace, 2000, p. 6; Lev and Radhakrishnan, 2003, 2005). Although a further refinement of the concept of intangible capital is still clearly needed, the overall measurement of the different

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dimensions of intangible capital has largely improved, and past commentaries, which have called into question the possibility of measuring certain dimensions of intangible capital, seem to have been too pessimistic.[1] Nevertheless, it remains an open question which range of intangible capital indicators should be incorporated into the asset boundary (Hill, 2009; Stiglitz *et al.*, 2009) and which dimensions should be included in a definition of intangible capital (World Bank, 2006).

This paper focuses on intangible capital investment by *businesses*. Using international comparable data on business intangible capital investment generated within the INNODRIVE project[2] (INNODRIVE, 2011; Jona-Lasinio *et al.*, 2011), the paper aims to present new econometric evidence about the impact of investments in business intangible capital on labor productivity growth within the business sector. As envisaged in the INNODRIVE framework (Jona-Lasinio *et al.*, 2011), the dimensions of business intangible capital were generated along the framework originally proposed by Corrado *et al.* (2005, 2009). However, as the author wholly shares the view of the World Bank (2006), that the dimensions of human and social capital should also be classified as intangible capital, the dimensions of human and social capital have been included in the Total Factor Productivity (TFP) term of the utilized model specification.

2. Theoretical Links between Business Intangible Capital and Labor Productivity Growth

2.1. *Theoretical Relationship between Intangible Capital and Labor Productivity Growth*

The importance of Business Enterprise Research & Development (BERD) and innovation was explicitly recognised in the "Lisbon process" and has been adopted by the European 2020 strategy for smart, sustainable, and inclusive growth (European Commission, 2010). Although the importance of business investment in Research & Development has already been widely acknowledged—

[1]As recently as 1999, Robert Solow criticized the introduction of the term "social capital" into the discipline of economics, by highlighting that "the term *capital* stands for a stock of produced or natural factors of production that can be expected to yield productive services for some time." He continues to state that: "Originally, anyone who talked about capital had in mind a stock of *tangible*, solid, often durable things such as buildings, machinery, and inventories" (Solow, 1999, p. 6; emphasis added). Ten years later the concept of *intangible capital* (including social and human capital) seems to have found its way into the economic discipline. Other than the notion of social capital, *intangible* capital defines itself exactly as not being *tangible*. Hence, the term intangible capital seems to offer an umbrella term for all those capital forms that are theoretically important for productivity but are not *tangible* in nature. A very similar definition is used in the World Bank (2006) book entitled *Where is the Wealth of Nations?* in which the authors use intangible capital as an umbrella term for human capital, the skills and know-how of the workforce, social capital, the level of generalized trust among citizens and an economy's institutional framework, such as an efficient judicial system and clear property rights, which will influence the overall economy positively.

[2]The INNODRIVE (Intangible Capital and Innovations: Drivers of Growth and Location in the EU) project consists of the National Intangibles Database and the Company Intangibles Database. The INNODRIVE National Intangibles Database provides time series of the Gross Fixed Capital Formation for different intangible capital components for the EU-27 countries and Norway. This dataset is utilized in the following empirical analysis and is cited as INNODRIVE 2011. A detailed description of the dataset is given in Jona-Lasinio *et al.* (2011). The goal of the INNODRIVE macro approach was to replicate the intangible capital measures which were produced by Corrado *et al.* (2005, 2009) for the U.S. for the EU.

by policy-makers and in economic theory—our knowledge of the contribution of business intangibles to labor productivity growth is still incomplete. Generating a wider concept of innovation and focusing on the issue of a possible revision of the national accounting framework, Corrado *et al*. (2005) have grouped various items that constitute the knowledge of the firm into three basic categories: (i) computerized information, (ii) innovative property, and (iii) economic competencies.

Whereas computerized information includes knowledge which is enclosed in computer programs and computerized databases, innovative property includes the *scientific* knowledge embedded in patents, licenses, and general know-how, as well as "the innovative and artistic content in commercial copyrights, licences and designs" (Corrado *et al*., 2005, pp. 23–26). Corrado *et al*. (2005, p. 28) define the economic competencies category of intangibles as "the value of brand names and other knowledge embedded in firm-specific human and structural resources." It includes expenditures on advertising, market research, firm-specific human capital, and organizational capital. These measures indicate that the potential of intangible capital for stimulating productivity growth lies in the provision of knowledge, an increase in the selling potential of a product, and the development of processes and a productive environment for the actual physical production of a good, or as van Ark *et al*. (2009, p. 63) stress, that products and services are becoming more knowledge-intensive.

While the positive relationship between computerized information, here in particular via an interaction effect with organizational capital (Brynjolfsson *et al*., 2002), and certain dimensions of innovative property (scientific R&D) (Lichtenberg, 1993; Coe and Helpman, 1995; Park, 1995; Guellec and van Pottelsberghe de la Potterie, 2001) on labor productivity growth has already been discussed extensively, it seems important to stress once more the theoretical importance of the single dimensions of economic competencies, namely brand names, firm-specific human capital, and organizational capital.

In theory, *brand names* should positively affect labor productivity growth since an important aspect of today's products is the "image" attached to them. Cañibano *et al*. (2000) argue that the ownership of a brand that is appealing to customers permits a seller to acquire a higher margin for goods or services that are like those offered by competitors. As the consumer's choice among the products of competing firms is often motivated by a perception of reliability and trustworthiness, the development of this image or brand has to be considered pivotal in the yield of future benefits. Expenditure on market research compromises, next to expenditure on advertising, an important part of the investment in brand equity.

Firm-specific human capital is another important asset of a firm. Cañibano *et al*. (2000) stress that a firm with more competent employees is likely to acquire higher profits than competitors whose workers are less skilled. In this regard Abowd *et al*. (2005) argue that the value of companies will increase if the quality of their human resources increases.

In addition to the "image" projected by a firm or a product and the quality of the training of workers, the management of a production process involving highly technological physical capital has also become important. As goods become more and more sophisticated, production processes are becoming more complex and the *organizational capital* of a firm becomes crucial. Lev and Radhakrishnan

(2005, p. 75) define organizational capital as "an agglomeration of technologies—business practices, processes and designs and incentive and compensation systems—that together enable some firms to consistently and efficiently extract from a given level of physical and human resources a higher value of product than other firms find possible to attain." Organizational capital is seen by them (Lev and Radhakrishnan, 2003, 2005) as the only competitive asset truly owned by a firm, while the others are tradable and thus available for every firm that wants to invest in them.

2.2. *The Treatment of Intangible Expenditures*

Although, as argued above, the existing literature widely recognizes the importance of the various dimensions of business intangible capital for the enhancement of growth, in contemporary accounting practice, however, intangibles are treated as intermediate expenditures and are not classified as investments in Gross Fixed Capital Formation (GFCF). This situation has improved with the inclusion of software, mineral exploration, and entertainment, literary, and artistic originals into the asset boundary of the national accounts. Moreover, for innovative properties such as scientific R&D investment, national accounts have started to set up satellite accounts.

In the economic literature this situation has gradually improved by Corrado *et al.*'s (2005) approach to capitalize the above-mentioned intangibles. Utilizing standard intertemporal capital theory, they define investments as "any use of resources that reduces current consumption in order to increase it in the future" (Corrado *et al.*, 2005, pp. 17–19) and treat intangibles, in contrast to the national accounting framework, as investments rather than intermediate goods; thus including it in the asset boundary rather than netting it out. Corrado *et al.* (2009, pp. 663–66) model the impact of capitalizing intangible assets on the sources-of-growth model as follows:

$$g_Q(t) = s_L(t)\,g_L(t) + s_K(t)\,g_K(t) + s_R(t)\,g_R(t) + g_A(t) \quad (1)$$

where Q is GDP expanded by the flow of new intangibles, $g_X(t)$ denotes the rate of growth of the respective variables, and $s_X(t)$ represents the input shares. L is labor, K is the tangible capital stock, R is the intangible capital stock, and A is the TFP term.

3. Estimates of Intangible Capital Investment

Following Corrado *et al.* (2005, 2009) the INNODRIVE macro approach (INNODRIVE, 2011; Jona-Lasinio *et al.*, 2011) has classified business intangible capital investment into three groups: (i) computerized information, (ii) innovative property, and (iii) economic competencies. Moreover it differentiates two "old" intangible capital variables[3]—(i) software and (ii) mineral exploration and

[3]In the INNODRIVE macro approach (INNODRIVE, 2011), software and mineral exploration, and copyright and license costs (for the development of entertainment, literary, and artistic originals) are considered national account intangibles (i.e., they have already been included in the national accounts), whereas the other intangibles are considered as new intangibles.

copyright and license costs[4]—to eight new intangible capital variables: (iii) scientific R&D, (iv) new product development in the financial services industry, (v) new architectural and engineering designs, (vi) advertising, (vii) market research, (viii) firm-specific human capital, (ix) own account, and (x) purchased component of organizational capital.

The first group, computerized information, contains: (i) computer software. Computer software was measured by using data from the EUKLEMS[5] project, as well as official national account data and the use table from the supply and use framework (Jona-Lasinio *et al*., 2011, pp. 35–36).

The second group, innovative property, contains the following variables: (ii) scientific R&D, (iii) new product development in the financial services industry, (iv) new architectural and engineering designs, and (v) mineral exploration and copyright and license costs.

To measure investment in *scientific R&D*, data on expenditure on R&D by businesses were retrieved from Eurostat. To avoid double-counting of software investment and investment in the development of new products within the financial services industry, data for the subsector K72 (computer and related activities) and sector J (financial intermediation) were subtracted from the R&D expenditure. In accordance with Corrado *et al*. (2005), expenditure in scientific R&D was considered a 100 percent investment in intangible capital (Jona-Lasinio *et al*., 2011, pp. 37–39).

Mineral exploration and copyright and license costs were measured with the help of data from the national accounts and the use tables from the supply and use frameworks (Jona-Lasinio *et al*., 2011, p. 39).

The investment in *new architectural and engineering designs* has been measured using data from the national accounts (Jona-Lasinio *et al*., 2011, pp. 40–41).

Investment in *new product development in the financial services industry* was measured, according to Corrado *et al*. (2005), on the basis of 20 percent of total intermediate spending for intermediate inputs by the financial intermediation industry, which is defined as excluding insurance and pension funding (NACE J65) (Jona-Lasinio *et al*., 2011, pp. 41–42).

The third group, economic competencies, contains the following variables: (vi) advertising expenditure, (vii) expenditure on market research, (viii) firm-specific human capital, (xi) own account development of organizational structure, and (x) purchased organizational structure.

To measure investment in *advertising*, a private data source (Zenith Optimedia) was used.[6] Zenith Optimedia data reports the expenditure on advertising in newspapers and other media which should capture the purchased and own-account expenditure. Following Corrado *et al*. (2005), who followed Landes and Rosenfield (1994), only 60 percent of the actual expenditure was considered investment (Jona-Lasinio *et al*., 2011, pp. 42–44). In order to measure the investment in market research, data on the turnover of subsector K7413 (Market Research and

[4]In contrast to Corrado *et al*. (2005, 2009), the INNODRIVE macro approach (INNODRIVE, 2011) has merged these two variables when presenting the final investment data.

[5]EUKLEMS refers to the research project "Productivity in the European Union: A Comparative Industry Approach" and stands for EU level analysis of capital (K), labor (L), energy (E), materials (M), and service (S) inputs. The data can be downloaded at: http://www.euklems.net/.

[6]Felix Roth is grateful to Zenith Optimedia for making the data available to him.

Public Opinion Polling) from Eurostat's Structural Business Statistics on Business Services were taken. Following the approach of Corrado *et al.* (2005), the prevalence of own-account market and consumer research was estimated by doubling the estimate of the data on market research (Jona-Lasinio *et al.*, 2011, pp. 44–46).

Data on *firm-specific human capital* were taken from Eurostat's Continued Vocational Training Survey. This variable is a measure of the training expenditure by enterprises and it is computed as the cost of continued vocational training courses as a percentage of total labor costs multiplied by employee compensation. This training expenditure was considered a 100 percent investment in intangible capital. The estimation method is applied at the industry level to guarantee that the compositional changes of industries are taken into account. The measures are then aggregated to obtain data on the national level (Jona-Lasinio *et al.*, 2011, pp. 46–49).

Organizational capital is measured by the own-account and purchased investment in the organizational structure of a firm. Data on the own-account component of organizational capital are taken from the EU Structure of Earnings Survey (in 2002) and the EU Labor Force Survey. Own-account organizational capital is represented by the compensation of the management. Manager compensation is computed as the manager compensation share multiplied by the compensation of all employees. The manager compensation share is the share of gross earnings of managers over the gross earnings of all employees. Following Corrado *et al.* (2005) it was assumed that 20 percent of manager compensation is spent on investment in the organizational structure of a firm. Data on the purchased component of organizational capital are taken from Eurostat's Structural Business Statistics on Business Services and the FEACO[7] Survey of the European Management Consultancy Market. Purchased organizational capital is represented by management consultant fees. In order to compute the purchased component of organizational capital, the nominal gross output or turnover of NACE 7414 (business and management consultancy activities) was used. It was assumed that 80 percent of business sector expenditure is considered an investment (Jona-Lasinio *et al.*, 2011, pp. 49–54, 61–62).

As can be inferred by the INNODRIVE macro-dataset (INNODRIVE, 2011) all investment rates were constructed for the non-farm business sector, thus for NACE sectors c–k+o.[8]

4. Previous Empirical Results

Several empirical studies try to estimate the importance of business intangible assets for labor productivity growth. Up to now all existing studies utilize

[7]FEACO stands for "Fédération Européene des Associations de Conseils en Organisation".

[8]NACE stands for "Nomenclature Générale des Activités Economiques dans I'Union Européenne" and covers sectors from a to q. According to NACE rev. 1.1, sectors c to k plus o cover the non-farm (a + b) market sectors: mining and quarrying (c), manufacturing (d), electricity, water, and gas supply (e), construction (f), wholesale and retail trade (g), hotel and restaurants (h), transport, storage, and communication (i), financial intermediation (j), real estate, renting, and business activities (k), and other community, social, and personal service activities (o). They exclude: public administration, defense, and compulsory social security (l), education (m), health and social work (n), activities of households (p), and extra-territorial organizations and bodies (q).

a growth accounting methodology.[9] There is an extensive literature studying intangible capital investment both at the micro (firm) level (e.g., Brynjolfsson and Yang, 1999; Webster, 2000; Brynjolfsson *et al.*, 2002; Cummins, 2005; Lev and Radhakrishnan, 2005) and at the macro (national) level. A detailed summary of the micro-economic studies as mentioned above is not undertaken here as this analysis focuses solely on the macro-economic level.

Recent literature on the macro-economic level has highlighted three important lines of results once capitalizing intangibles: (i) the share of intangible capital investments as a percentage of GDP or market sector gross value added (MGVA), (ii) the contributions of intangible capital on output growth within an accounting framework, and (iii) the growth acceleration induced once capitalizing intangibles. Table 1 provides an overview of these three dimensions within the most recent published literature in this field. Corrado *et al.* (2005) find for the United States that the investment in business intangibles was 10–12 percent of existing GDP between 1998 and 2000 and approximately 13 percent of non-farm business output in 2003 (see figure 2 of Corrado *et al.*, 2009, p. 673). In line with Corrado *et al.*, Nakamura (2010, p. S138), when analyzing a timeframe from 1959–2007, finds that investments in intangibles become as important as investment in tangibles in the U.S. around 2000. Marrano *et al.* (2009) show that in the United Kingdom the private sector spent a sum equivalent to 13 percent of adjusted MGVA on business investment in intangibles in 2004. A working paper by Jalava *et al.* (2007) finds that the Finnish investment in non-financial business intangibles was 9.1 percent of unrevised GDP in 2005. Fukao *et al.* (2009) estimate 11.1 percent of GDP was invested in intangible capital in Japan in 2000–05. According to Hao *et al.* (2009), Germany and France invested 7.1 and 8.8 percent, respectively, and Italy and Spain invested 5.2 percent in intangibles in the market sector over GDP in 2004. A working paper by Van Rooijen-Horsten *et al.* (2008) finds an investment share for intangibles of 8.3 percent of GDP when general government industry is excluded for the Netherlands in 2001–04. Van Ark *et al.* (2009) find intangible investment shares in the market sector of 6.5 percent in Austria, 6.5 percent in the Czech Republic, and 7.9 percent of GDP in Denmark in 2006.[10] Investments for the U.K., Germany, France, Italy, Spain, and the U.S. are similar to these in the other papers. Edquist (2011) finds that in Sweden, total business investment in intangibles was equivalent to 10 percent of GDP, or approximately 16 percent of the business sector gross value added (GVA) in 2006.

Second, when looking at the contribution of intangible capital to output growth, Corrado *et al.* (2009) find for the U.S. that 27 percent of labor productivity growth in 1995–2003 is explained by intangible capital. Marrano *et al.* (2009) find that 20 percent of labor productivity growth is accounted for by intangible capital deepening in 1995–2003 in the United Kingdom. Jalava *et al.* (2007) find that intangible capital accounts for 16 percent of labor productivity growth in

[9]For a more detailed discussion, see Barro and Sala-i-Martin (2004, pp. 433–60) or Temple (1999, pp. 120–21).

[10]The authors also provide estimates for Greece and Slovakia. These are not reported here as they are not part of the country sample in this paper.

TABLE 1

Summary of Existing Empirical Studies

Article	Country	Investment (as a % of GDP)	Contribution to LPG in %[a]	Growth Acceleration in %
Corrado *et al.* (2005)	U.S.	10–12 (98–00)	/	/
Nakamura (2010)	U.S.	Intangible = Tangible (00–07)	/	/
Corrado *et al.* (2009)	U.S.	~13[f] (03)	27 (95–03)	11.2 (95–03)
Marrano *et al.* (2009)	U.K.	13[b] (04)	20 (95–03)	13.1 (95–03)
Fukao *et al.* (2009)	JAP	11.1 (00–05)	27, 16 (95–00), (00–05)	17.3, –1.4 (95–00), (00–05)
Jalava *et al.* (2007)	FI	9.1 (05)	16, 30 (95–00), (00–05)	13.2, 2.1 (95–00), (00–05)
Van Rooijen-Horsten *et al.* (2008)	NL	8.3[d] (01–04)	/	/
Hao *et al.* (2009)	DE, FR, IT, ES	7.1, 8.8, 5.2, 5.2 (04)	31, 37, 59, 64 (95–03)	10.5, 13.8, 37.2, 40 (95–03)
Van Ark *et al.* (2009)	DE, FR, IT, ES, AT, CZ, DK	7.2, 7.9, 5.0, 5.5, 6.5, 6.5, 7.9 (06)	21, 24, 41, 26, 23, 15, 34 (95–06)[c]	11.2, 9.3, 11.5, 30.6, 18.6, 2.2, 37.0 (95–06)[c]
Edquist (2011)	SE	10/~16[e] (04)	41, 24 (95–00), (00–06)	16, –2.3 (95–00), (00–06)

Notes:
[a]LPG = Labor Productivity Growth.
[b]Measure here is adjusted MGVA.
[c]Only for Czech the period ranges from 1997 to 2006.
[d]Measure here is intangible capital spending excluding general government industry.
[e]Measure here is GVA.
[f]Measure here is non-farm business output.
AT = Austria, CZ = Czech Republic, DE = Germany, DK = Denmark, ES = Spain, FI = Finland, FR = France, IT = Italy, JAP = Japan, NL = Netherlands, SE = Sweden, U.K. = United Kingdom, U.S. = United States.
The numbers in parentheses refer to the relevant time periods.

1995–2000 and for 30 percent in 2000–05 in the Finish case. Fukao *et al*. (2009) show that intangible capital explains 27 percent of the Japanese growth rate in 1995–2000 and 16 percent in 2000–05. Hao *et al*. (2009) find that intangibles account for 31 percent of labor productivity growth in Germany, 37 percent in France, 59 percent in Italy, and 64 percent in Spain. Van Ark *et al*. (2009) find that in Germany, France, Italy, Spain, Austria, the Czech Republic, and Denmark, intangible capital accounts for, respectively, 21, 24, 41, 26, 23, 15, and 34 percent of labor productivity growth. Finally, Edquist (2011) finds for Sweden that the contribution of intangible capital drops from 41 percent in the period 1995–2000 to 24 percent from 2000 to 2006.

Third, overall the capitalization of intangible capital accelerates productivity growth. Detailed results of the growth acceleration values will be discussed in comparison with the INNODRIVE data in Section 6.

5. Model Specification, Research Design, and Data

5.1. *Model Specification*

The model specification within this paper follows an approach by Benhabib and Spiegel (1994), which Temple (1999) coined "cross-country growth accounting" or "growth accounting with externalities" (p. 124). The model by Benhabib and Spiegel (1994) differs from the framework of traditional single growth accounting methodology as depicted by equation (1) by two components. First, the output elasticities are estimated, rather than imposed. Second, part of the model can be designed to explain the international variance in TFP growth.

One advantage of the utilization of stock data for tangible and intangible capital in contrast to other econometric growth estimations (e.g., Mankiw *et al*., 1992) is that one is able to estimate the production function without the term for initial efficiency and thus without "the complexities of dynamic panel data models, provided that TFP growth is unrelated to initial income" (Temple, 1999, p. 125). Like the approach by Fleisher *et al*. (2010), the empirical model by Benhabib and Spiegel (1994) is applied in a panel context.

Following the theoretical framework of Corrado *et al*. (2009) as depicted in equation (1), Benhabib and Spiegel's (1994) model specifications are expanded by intangibles. The starting point for the estimation is then an augmented Cobb–Douglas production function,

$$Q_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{\gamma} R_{i,t}^{\beta} \varepsilon_{i,t}, \tag{2}$$

where intangible capital R is added to the conventional production function because it is treated as investments rather than intermediate expenses. $Q_{i,t}$ is GVA (non-farm business sectors c–k+o excluding real estate activities) expanded by the investment flows in intangible capital in country i and period t. Similar to equation (1), K is the tangible capital stock, L is labor, and A is TFP. Assuming constant returns to scale and rewriting the Cobb–Douglas production function in intensive form, the following equation is obtained:

$$q_{i,t} = A_{i,t} k_{i,t}^{\alpha} r_{i,t}^{\beta} \varepsilon_{i,t} \tag{3}$$

with lower case letters indicating variables in terms of total hours worked. If differences in natural logarithms are taken, the annual growth relationship can be expressed as follows:

$$(lnq_{i,t} - lnq_{i,t-1}) = (lnA_{i,t} - lnA_{i,t-1}) + \alpha(lnk_{i,t} - lnk_{i,t-1}) + \beta(lnr_{i,t} - lnr_{i,t-1}) + u_{i,t} \tag{4}$$

where:

$$u_{i,t} = ln\varepsilon_{i,t} - ln\varepsilon_{i,t-1}. \tag{5}$$

Unless the TFP growth term is estimated, the estimation of this equation will be biased (Benhabib and Spiegel, 1994; Temple, 1999). Therefore, using a similar but extended approach to Benhabib and Spiegel (1994), a model for $(lnA_{i,t} - lnA_{i,t-1})$ is specified as follows:

$$\begin{aligned}(lnA_{i,t} - lnA_{i,t-1}) = c + gH_{i,t} + mH_{i,t}\frac{(Q_{\max,t} - Q_{i,t})}{Q_{i,t}} + n(1 - ur_{i,t}) \\ + p\sum\nolimits_{j=1}^{k} X_{j,i,t} + cd_{i,t=2001}\end{aligned} \tag{6}$$

where the constant term c represents exogenous technological progress, the level of human capital ($gH_{i,t}$) reflects the capacity of a country to innovate domestically, the term $mH_{i,t}\frac{(Q_{\max,t} - Q_{i,t})}{Q_{i,t}}$ proxies a catch-up process, the term $n(1 - ur_{i,t})$ takes into account the business cycle effect,[11] the term $p\sum_{j=1}^{k} X_{j,i,t}$ is a sum of k extra policy variables which could possibly explain TFP growth, and $cd_{i,t=2001}$ is a crisis dummy to control for the economic downturn in 2001 after the burst of the IT (information technology) bubble in the year 2000 and the 9/11 attack in 2001. Inserting equation (6) into equation (4) provides the baseline model to be estimated within the econometric estimation in Section 7:

$$\begin{aligned}(lnq_{i,t} - lnq_{i,t-1}) = c + gH_{i,t} + mH_{i,t}\frac{(Q_{\max,t} - Q_{i,t})}{Q_{i,t}} + n(1 - ur_{i,t}) + p\sum\nolimits_{j=1}^{k} X_{j,i,t} \\ + cd_{i,t=2001} + \alpha(lnk_{i,t} - lnk_{i,t-1}) + \beta(lnr_{i,t} - lnr_{i,t-1}) + u_{i,t}\end{aligned} \tag{7}$$

5.2. *Research Design*

The econometric analysis covers 13 EU-27 countries for a time period from 1998 to 2005. The countries included are Germany, France, Italy, United

[11]Similar to Guellec and van Pottelsberghe de la Potterie (2001, pp. 107–16), as the research design of this paper uses yearly growth data, a control for the business cycle is specified as $(1 - ur_{i,t})$. The analysis by de la Fuente (2002, p. 580) uses only $ur_{i,t}$.

Kingdom, Spain, Sweden, Denmark, Finland, Austria, Ireland, the Netherlands, Slovenia, and the Czech Republic.[12] Although the INNODRIVE Macro approach (INNODRIVE, 2011) has managed to produce a complete set of intangible capital variables for all 27 EU countries plus Norway, the following econometric analysis had to be restricted to a maximum of 13 EU countries due to a lack of sectoral tangible capital input data within the EUKLEMS database. With the 13 countries and the given timeframe this leaves the analysis with 98 overall observations (the Czech Republic and Slovenia each miss three time observations from 1998–2000). Following existent empirical studies (e.g., Bassanini and Scarpetta, 2001), annual growth rates over the time period 1998–2005, rather than long-term growth rates from 1998–2005, have been chosen to be able to apply a panel data analysis.[13] With intangible capital stocks having been calculated for the period 1995–2005, the econometric analysis was restricted to a time frame of 1998–2005 as the calculation of capital services (as can be depicted in Supplementary Appendix A2) needed intangible capital stock information from 1995–97 to produce intangible capital service growth for the year 1998. The whole research design applies to non-farm business sectors c–k+o. The output measure is GVA for the non-farm business sectors c–k+o excluding real estate activities. Tangible and intangible are non-farm business investments c–k+o. Tangible capital investments excluded residential capital.

5.3. *Data*

The data for the following econometric analysis were taken from various different data sources as described below:

- Data on the single components of intangible capital were taken from the INNODRIVE macro dataset (INNODRIVE, 2011). The INNODRIVE macro data to a large extent conforms to EUKLEMS data, and GFCF data is provided for all intangible assets and all EU-27 countries plus Norway.
- Data on GVA (non-farm business sectors excluding real estate activities), tangible capital stocks, capital compensation, gross fixed tangible capital investments, tangible investment price indices, labor input (number of hours worked per persons engaged) and depreciation rates for tangible capital were calculated from the EUKLEMS database. Tangible capital included communications equipment, computing equipment, total non-residential investment, other machinery and equipment, transport equipment, and other assets, but excluded residential capital.
- Human capital is measured as the "percentage of population who attained at least upper secondary education," which is taken as a proxy for the inherent stock of human capital. These data are provided by Eurostat.
- The variable rule of law is taken from the Worldwide Governance Indicators project (Kaufmann *et al.*, 2010). The World Bank (2006) uses this

[12]Felix Roth wishes to thank Mary O'Mahony for making available the capital input data for France and Ireland.

[13]By using annual data this paper assumes that intangible capital stocks have an immediate effect on labor productivity growth that specific year. By contrast, the growth accounting approaches, as described before, take into account the long-term effects of capital services.

indicator as a proxy for generalized trust, an important indicator of social capital (Roth, 2009).

- The data on openness to trade are retrieved from the Penn World Table Version 6.2 (Heston *et al.*, 2006).
- The data on unemployment rates, the stocks of foreign direct investment (FDI) (as a % of GDP), total government expenditure (as a % of GDP), total expenditure on social protection (as a % of GDP), total general government expenditure on education (as a % of GDP), inflation rates (annual average rate of change in Harmonized Indices of Consumer Prices), taxes on income (as a % of GDP), and the stock market capitalization (as a % of GDP) are taken from Eurostat.

5.4. *A Note on the Construction of Intangible Capital Stocks*

Intangible capital stocks for the 11 EU-15 countries for the time period 1995–2005 were constructed by applying the perpetual inventory method (PIM) to series of intangible capital investments going back to 1980 and using the depreciation rates, δ_R, suggested by Corrado *et al.* (2009): 20 percent for scientific R&D, new architectural and engineering designs, and new product development in the financial services industry; 40 percent for own and purchased organizational capital and firm-specific human capital; and 60 percent for advertising and market research. In accordance with EUKLEMS for software, a depreciation rate of 31.5 was used.[14] Intangible capital stocks for the two transition countries, Slovenia and Czech Republic, were calculated by applying the PIM to investment flows from 1995–1999, constructing stocks for the six year period 2000–05. For the calculation of the intangible capital stock R_t the PIM takes the following form:

$$R_t = N_t + (1 - \delta_R) R_{t-1} \tag{8}$$

which assumes: (i) geometric depreciation, (ii) constant depreciation rates over time, and (iii) depreciation rates for each type of asset are the same for all countries. The real investment series for N_t use a GVA price deflator which is the same for all intangible assets.

5.5. *A Note on the Construction of Intangible and Tangible Capital Services*

Data on intangible capital services were generated according to the literature by Oulton and Srinivasan (2003) and Marrano *et al.* (2009), and are consistent with the EUKLEMS approach (Timmer *et al.*, 2007). This literature argues that rather than using a wealth measure for capital (like the capital stock), it is crucial to derive the flow of services a capital stock can provide to production. An overview of the technical steps in how intangible and tangible capital services were constructed is given in Appendix A2.

[14]Intangible capital stocks on mineral exploration and copyright and licence costs had to remain in the tangible capital stock as they could not be distinguished from tangible assets in the rest category "other" in the EUKLEMS dataset.

6. Descriptive Analysis

Table A1 in Appendix A1 shows the descriptive statistics of the data utilized over the 13 EU countries and over the time period 1998–2005. Annual labor productivity growth increases by 0.10 (from 2.3 to 2.4) percentage points, or by 4.4 percent, when taking into account the contribution of intangibles in the measure of GVA. This value is smaller than most values reported by the existing literature as depicted in Table 1, which find that productivity growth increased by 11 percent in Germany, 9–14 percent in France, 11–37 percent in Italy, 31–40 percent in Spain, 19 percent in Austria, 37 percent in Denmark, and 13 percent in the U.K. when adding intangible capital to the asset boundary. The mean value of 4.4 percent however is larger than the value for Sweden of –2.3 percent, for Finland of 2.1 percent, and the Czech Republic with 2.2 percent. The descriptive results in Table A1 also show that the services of the intangible capital stock (4.1 percent) grow on average faster than the services of the tangible capital stock (3.3 percent).

Figure 1 shows the business intangible capital investments over GVA for the ten single intangible assets and the three core dimension as described in Section 3. Overall business intangible capital investments differ considerably across the 13

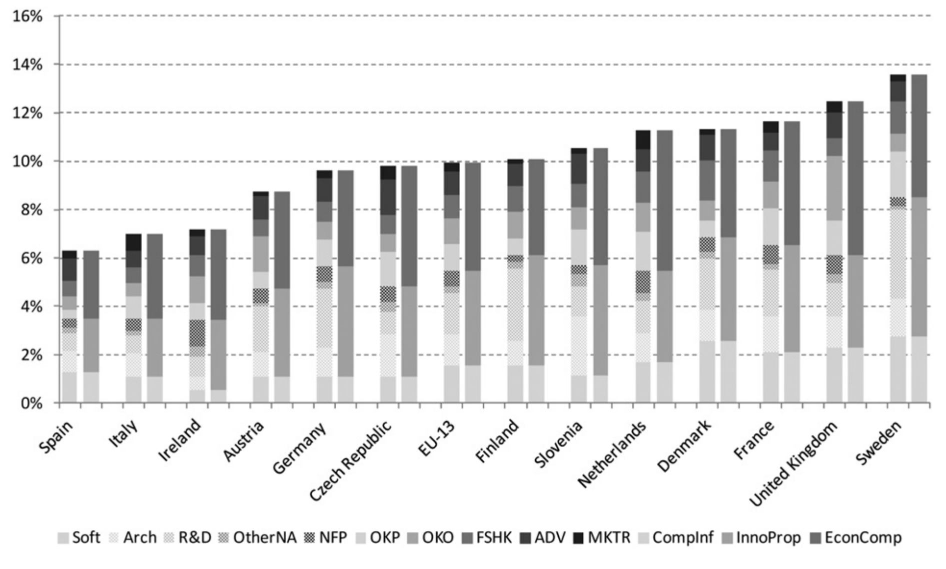

Figure 1. Business Intangible Investment (as a percentage of GVA) in 13 EU Countries, 1998–2005

Notes: The left bar chart for each country shows all ten single intangible capital items and the right bar chart indicates the three dimensions: Computerized Information, Innovative Property, and Economic Competencies. All variables in the graph are compared to GVA (non-farm business sector c–k+o excluding real estate activity). Soft = Software, Arch = New architectural and engineering designs, NFP = New product development in the financial services industry, R&D = Scientific research and development, Other NA = Other national account intangibles (mineral exploration and copyright and licence costs), OKP = Organizational capital (purchased component), OKO = Organizational capital (own account component), FSHK = Firm-specific human capital, ADV = Advertising, MKTR = Market research, CompInf = Computerized Information, InnoProp = Innovative Property and EconComp = Economic Competencies.

Source: INNODRIVE data (INNODRIVE, 2011).

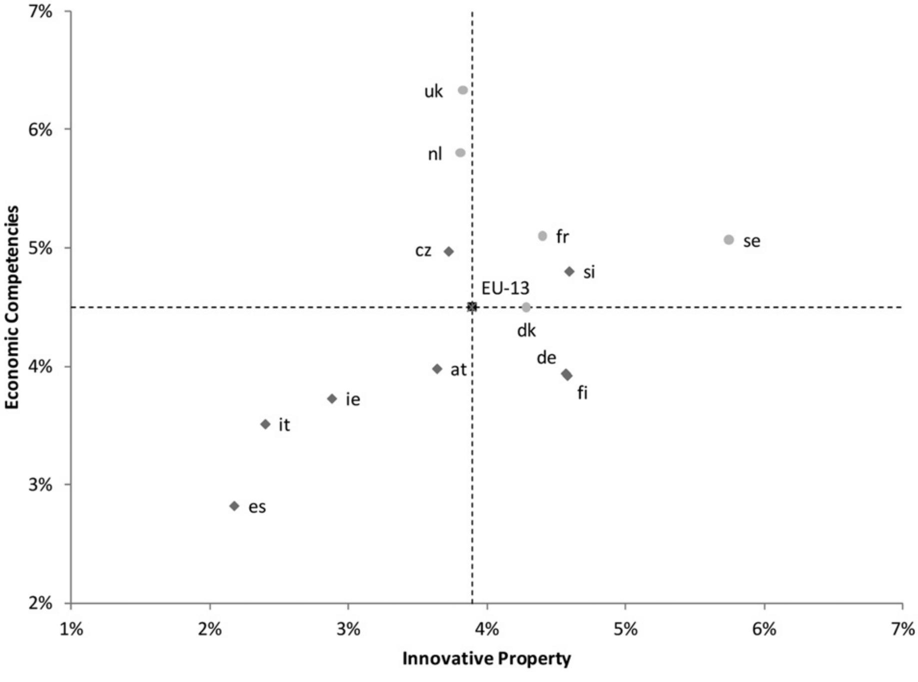

Figure 2. Scatterplot between Innovative Property and Economic Competencies (as a percentage of GVA), 1998–2005

Notes: EU-13 = mean value of all 13 countries; es = Spain, it = Italy, fr = France, fi = Finland, de = Germany, dk = Denmark, at = Austria, ie = Ireland, cz = Czech Republic, nl = Netherlands, si = Slovenia, uk = United Kingdom; ◆ = Low Computerized Information, ● = High Computerized Information.

Source: INNODRIVE data (INNODRIVE, 2011).

EU countries used in the econometric estimation.[15] Sweden ranks first, with an overall investment of 13.6 percent of GVA. As can be inferred from Table 1, this is within the range of the values pointed out by Edquist (2011), who finds investment rates of 10 percent over GDP and 16 percent over business GVA. Sweden is followed by the U.K., which has an investment rate of intangible capital of 12.4 percent. As depicted in Table 1, this is quite similar to the value for the U.K., as measured by Marrano *et al*. (2009), of 13 percent. The U.K. is followed by the second largest economy, France, with an investment rate of 11.6 percent. This investment rate of France is in the range of the results of Hao *et al*. (2009), who report that France invests 8.8 percent of GDP. The two large Mediterranean economies of Italy and Spain are situated within the two last positions in the distribution. Spain invests 6.3 percent on intangibles and Italy around 7.0 percent on intangible capital. This again fits with the reported investment rate by Hao *et al*. (2009) of 5.2 and 5.2 percent, and van Ark *et al*. (2009), with investment rates of 5.5 and 5.0 percent over GDP. The largest European economy—Germany—is positioned in the middle of the distribution, with an overall investment of 9.6.

[15]For a comparison of the intangible capital investment in the EU-25, see Gros and Roth (2012).

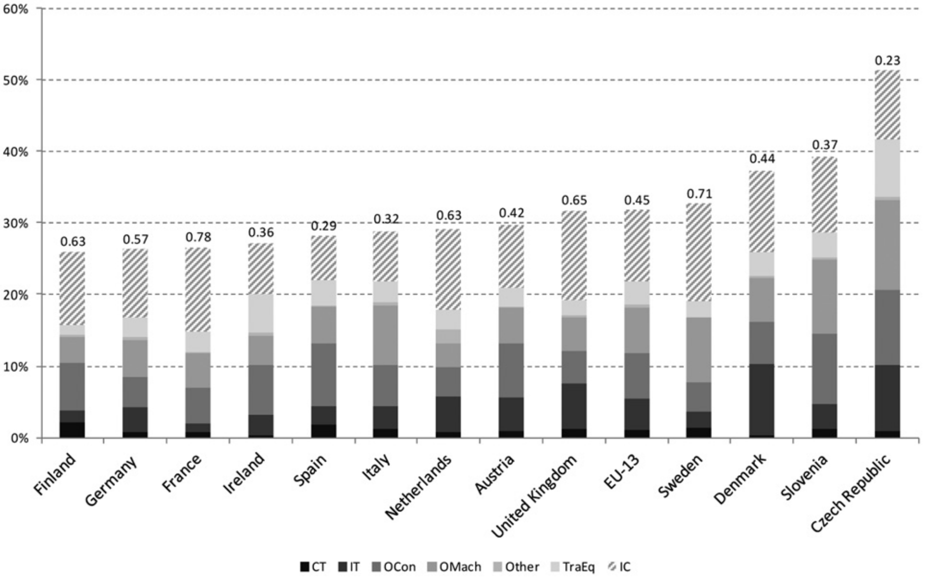

Figure 3. Business Tangible and Intangible Investment (as a percentage of GVA) in 13 EU Countries, 1998–2005

Notes: CT = Communications equipment, IT = Computing equipment, OCon = Total non-residential capital investment, OMach = Other machinery and equipment, Other = Other assets, TraEq = Transport equipment, IC = Intangible capital. Residential capital has been excluded.
Source: INNODRIVE data (INNODRIVE, 2011) and EUKLEMS data.

This is in accordance with van Ark *et al*. (2009) and Hao *et al*. (2009), who find investment rates of 7.2 and 7.1 percent, respectively. On average the included 13 EU countries invest 9.9 percent in intangibles over GVA.

The right-hand bar charts in Figure 1 make clear that overall the largest shares of intangibles are in either economic competencies or innovative properties, and only a small part of the investment is inside the investment in software. In order to identify the distribution between the three dimensions in each country more clearly, Figure 2 shows a scatterplot between the two larger dimensions, innovative property and economic competencies. These are the countries that can be classified as being highly innovative and investing strongly into economic competencies, and which can be detected in the upper-right corner, namely Sweden, Slovenia, and France. In addition, France and Sweden score high on computerized information. On the other hand, these are the economies that invest more in innovative properties than in economic competencies, such as Denmark, Finland, and Germany. The third category includes those countries which score low on innovative property and high on economic competencies: the U.K., the Netherlands, and the Czech Republic.[16] The fourth category includes those

[16]One reason for this significant difference might be the fact that those economies which invest higher proportions in economic competencies are more specialized in the service sector. However, this argument will be more consistent for the Netherlands and the United Kingdom, than for the Czech Republic.

countries which score low on both dimensions: Austria, Ireland, Italy, and Spain. Overall, Figure 2 clarifies that the sole focus of the Europe 2020 strategy (European Commission, 2010) on R&D investment seems to be too narrow in view of the significant investments in economic competencies.

Figure 3 shows a comparison between business investments in intangible capital and tangible capital as it is used in the econometric estimation. Interestingly, one detects that when including intangible capital investments, the average investment for the 13 EU countries is over 30 percent of GVA. This value is significantly higher than when solely considering tangible investments. Values on top of the bar charts depict the ratio of intangible/tangible capital investment. Ratios close but still less than 1 indicate that intangible capital investment is almost as large as tangible capital. France, Sweden, the U.K., the Netherlands, and Finland have reached ratios of larger than 0.6, with France already having reached a value of 0.78. It thus seems sound to conclude that some EU countries have started to converge toward the U.S., for which Nakamura points out that investment in intangible capital has become as large as investment in tangible capital. In the transition countries Slovenia and Czech Republic, and the Mediterranean countries Spain and Italy, tangible capital still dominates investments, with ratios below 0.4 (ratios of 0.37, 0.23, 0.29, and 0.32 respectively).

7. Econometric Analysis

Without a lagged initial income term on the left-hand side, the baseline model in equation (7) may be estimated without the complexities of a dynamic panel analysis.[17] Thus when estimating equation (7) the standard methods of panel estimation are fixed effects or random effects. The fixed effects are calculated from differences within each country across time; the random-effects estimation, in contrast, incorporates information across individual countries as well as across periods.[18] The major drawback with random effects is, although being more efficient, it is consistent only if the country-specific effects are uncorrelated with the other explanatory variables. A Hausman specification test can evaluate whether this independent assumption is satisfied (Hausman, 1978; Forbes, 2000, p. 874). The Hausman test applied here indicates that a random effects model can be used.[19] In addition, to control for potential cross-sectional heteroskedasticity, a robust VCE estimator has been utilized.[20] As highlighted in Section 5.2, the random-effects estimation uses 13 countries with a total of 98 observations. It is a balanced panel, with two countries (Czech Republic and Slovenia) missing three time observations from 1998–2000. Regression 1 in Table 2 shows the estimation results when estimating the traditional production function (without the inclusion of intangible capital and specifically excluding

[17]For the complexities of modeling the lagged income term within the growth econometric equation, see, for example, Bond *et al.* (2001) and Roodman (2009a, 2009b).

[18]More precisely, a random effects estimator uses a GLS estimator which produces a matrix weighted average of the between and within results.

[19]The test statistic is $\chi^2(6) = 3.45$. This clearly fails to reject the null hypothesis of no systematic differences in the coefficients.

[20]Using a xtoverid command (Schaffer and Stillman, 2010) the Sargan–Hansen test statistic is $\chi^2(6) = 5.5$. This clearly fails to reject the null hypothesis of no systematic difference in the coefficients.

TABLE 2

Intangibles and Labor Productivity Growth; Random-Effects Estimations

Estimation Method	Random Effects	Random Effects	Random Effects	G2SLS
Equation	1	2	3	4
Intangible Services Growth	–	0.29***	–	0.25*
		(0.09)		(0.13)
Tangible Services Growth[a]	0.47***	0.29**	0.24**	0.30*
	(0.13)	(0.11)	(0.12)	(0.18)
Computerized Inf. Services Growth	–	–	0.03	–
			(0.03)	
Innovative Property Services Growth	–	–	0.09	–
			(0.09)	
Economic Comp. Services Growth	–	–	0.2***	–
			(0.05)	
Upper Secondary Education 15+	yes	yes	yes	yes
Catch-Up[a]	yes	yes	yes	yes
Business Cycle	yes	yes	yes	yes
Crisis Dummy 2001	yes	yes	yes	yes
Observations	98	98	98	72
Number of countries	13	13	13	13
R-square overall	0.40	0.51	0.56	0.53
R-square within	0.20	0.36	0.41	0.35
R-square between	0.63	0.72	0.77	0.81

Notes: Labor Productivity Growth was calculated with GVA of the non-farm business sectors c–k+o excluding real estate activities). Labor Productivity Growth is in all regressions, except in RE1, expanded with intangible capital. Robust standard errors are provided below coefficient estimates in parentheses. Tangible capital excludes residential capital. Intangible and tangible depict business (sectors c–k+o) services growth.

[a]For 1, this variable is without software but includes mineral exploration and copyright and license costs.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

software from the tangible capital investment).[21] The overall R-square value is 0.40, with a within R-square value of 0.20 and a between R-square value of 0.63. The growth of tangible capital services is positively associated with labor productivity growth and has a coefficient of 0.47, explaining a 65 percent share of labor productivity growth.[22] Regression 2 shows the same model specification when including intangible capital investment. When including intangible capital investment in the asset boundary, the overall R-square value increases by 11 percent percentage points to 0.51, the within R-square value increases by 16 percentage points to 0.36, and the between R-square value increases by 9 percentage points to 0.72. Growth of intangible capital services is positively related to labor productivity growth, with a coefficient of magnitude 0.29. With this magnitude, intangible capital is able to explain around 50 percent of labor productivity growth. As can be inferred from Table 1,

[21]It was not possible to exclude mineral exploration and copyright and license costs from the tangible assets as the EUKLEMS category "other" is a rest category and separate elements cannot be filtered out. Thus tangible capital services and GVA in regression 1 include mineral exploration and copyright and license costs but exclude software.

[22]Considering equation (7), with the mean value of $(lnq_{i,t} - lnq_{i,t-1})$ being 0.23, the mean value of $(lnk_{i,t} - lnk_{i,t-1})$ being 0.32, and α being 0.47, the calculation can be set up as follows: $(0.47 \cdot 0.32)/0.23 = 0.65$.

a value of 50 percent is in close range to the results of the growth accounting results for the relevant country cases within the given analysis of this paper; in particular the results from Hao *et al*. (2009), who find 59 percent for France, 59 percent for Italy, and 64 percent for Spain. It is larger than the value of Marrano *et al*. (2009) of 20 percent, however. Once including intangible capital, the impact of tangible capital diminishes to 40 percent. TFP then changes from 35 to 10 percent and is thus diminished by 25 percent. As intangible and tangible capital are able to explain 90 percent of labor productivity, the finding by Corrado *et al*. (2009) that capital deepening becomes the dominant source is sustained.

In order to assess which dimensions of intangible capital services are the main drivers of the positive relationship between intangible capital and labor productivity growth, regression 3 includes the three dimensions of (i) computerized information, (ii) innovative property, and (iii) economic competencies, instead of the overall intangible capital index. Interestingly, the main driver is not innovative property as expected from the guidelines of the Europe 2020 strategy (European Commission, 2010), but economic competencies.

When running growth regressions, such as in equation (7), one must be aware of the possibility that the left-hand side and the right-hand side variables will affect each other. More specifically, the growth of the factor inputs intangible and tangible capital deepening might be endogenous, affected by a common event such as an economic shock (Temple, 1999, p. 125), or stand in a bi-directional relationship with labor productivity; thus an increase in labor productivity growth might, for example, influence the agent's decision to invest in tangible and intangible capital. Following Temple (1999, p. 125), as the authors have not been able to retrieve valid *external* instruments,[23] for example for intangible capital, lagged levels of intangible and tangible capital as instruments were chosen. Regression 4 shows the estimation results when instrumenting with lagged levels of intangible and tangible capital.[24] A Sargan–Hansen test of overidentification confirms the validity of the utilized instruments.[25] After controlling for endogeneity, the relationship between intangible capital and labor productivity remains significant (90 percent level) and the coefficient is only slightly reduced to 0.25. Therefore, it seems valid to conclude that the estimation results from regression 2 were indeed unbiased and not affected by uncontrolled endogeneity. Thus, the following sensitivity analysis will further explore the robustness of the coefficient of intangible

[23]Which is quite common in such cases and normally leads to a weak instrument problem (Stock and Watson, 2007).

[24]To be precise, the first three lagged levels of tangible and intangible services growth have been utilized as instruments. Next to the lagged levels, the estimation has used education, the catch-up term, the business cycle control, and the crisis dummy as instruments adding up to a total of 10 instruments. With a rule of thumb being that the total amount of instruments used should be below the country cases (Roodman, 2009a, p. 128), the total usage of 10 instruments thus seems adequate. The use of too large an instrument collection tends to overfit endogenous variables as it weakens the Sargan–Hansen test (Roodman, 2009b). This is why typically difference and system gmm estimator should be applied in cases of large n and small t, as within the gmm methodology instruments tend to explode with increasing t (Roodman, 2009a, p. 99).

[25]A Sargan–Hansen test of the validity of the instruments was performed via the command xtoverid cluster-robust (Schaffer and Stillman, 2010) after the G2SLS estimation. With $\chi^2(4)$ a value of 7.3, the rejection of the null hypothesis fails. This indicates that the used instruments are valid.

TABLE 3
SENSITIVITY ANALYSIS FOR THE BASELINE RANDOM EFFECTS MODEL

Row	Specification Change	Coefficient on Intangibles	Standard Error	Countries	Observations	R-Square
	Baseline regression					
(1)	Baseline – RE2	0.29***	(0.09)	13	98	0.51
	Influential cases					
(2)	Ireland and Italy	0.24**	(0.10)	11	82	0.47
(3)	Sweden	0.35***	(0.09)	12	90	0.53
	Restructuring of data					
(4)	1998–2001	0.32***	(0.08)	13	46	0.46
(5)	2002–05	0.30*	(0.18)	13	52	0.57
	Restructuring of country sample					
(6)	Without transition	0.26***	(0.09)	11	88	0.47
(7)	Mediterranean	0.60***	(0.14)	2	16	0.91
(8)	Liberal	0.14	(0.18)	2	16	0.58
(9)	Coordinated	0.33***	(0.13)	4	32	0.58
(10)	Scandinavian	0.25	(0.26)	3	24	0.55
	Specifications					
(11)	Rule of law	0.28***	(0.08)	13	98	0.52
(12)	Openness	0.29***	(0.08)	13	98	0.57
(13)	FDI	0.31***	(0.08)	13	97	0.58
(14)	Government expenditure	0.29***	(0.08)	13	98	0.52
(15)	Social expenditure	0.28***	(0.08)	13	98	0.54
(16)	Education expenditure	0.29***	(0.09)	13	98	0.50
(17)	Inflation	0.29***	(0.09)	13	98	0.51
(18)	Income tax	0.29***	(0.09)	13	98	0.51
(19)	Stock market capitalization	0.30***	(0.10)	13	91	0.58
(20)	Forward BC	0.28***	(0.09)	13	98	0.50
(21)	Dummies for all years	0.22**	(0.10)	13	98	0.56
(22)	Dummy for 2000	0.22**	(0.09)	13	98	0.48
	Methods					
(23)	Jackknife	0.22***	(0.08)	13	98	0.56

Notes: The R-squared values represent the overall R-squared in a random effects regression. Robust standard errors are provided in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

capital on labor productivity growth, from regression 2, permitting us to conduct an analysis with a maximum of 98 observations.

7.1. *Sensitivity Analysis*

Table 3 shows a sensitivity analysis of regression 2 in Table 2. The first row, under the title *Baseline regression*, depicts the coefficient of regression 2 in Table 2. The second and third row exclude potential influential cases from the country sample.[26] Thus in row 2 of Table 3, Ireland and Italy are excluded from the country sample. After the exclusion, the intangible capital coefficient is reduced (0.24) and remains significant at the 95 percent level. With Sweden being an outlier in opposition to the positive relationship, when excluding Sweden in row 3 the relationship gets significantly larger, with a coefficient of 0.35. When restructuring

[26]These cases have been detected by the usage of the command xtdata (Stata Corporation, 2007, pp. 59–64). Results can be obtained from the authors upon request.

the data in rows 4 and 5 into the two time periods 1998–2001 and 2002–05, we detect that the relationship seems to be slightly stronger in the time period 1998–2001 (0.32) than in 2002–05 (0.30). In addition, the relationship is highly significant in the 1998–2001 time period and only significant at the 90 percent level in the 2002–05 time period. Since the EU-13 country sample analyzed is very heterogeneous considering its economic structure, rows 6–10 explore the different regime typologies.[27] Excluding the two transition countries Czech Republic and Slovenia from the country sample does not alter the coefficient in a significant manner. Whereas the four coordinated (Germany, Austria, the Netherlands, and France) and two Mediterranean cases (Spain and Italy) remain highly significant, the two liberal cases (Ireland and the U.K.) and the three Scandinavian cases (Sweden, Denmark, and Finland) lose significance. Moreover, the coefficient increases significantly for the Mediterranean case.

Since labor productivity growth might be related to many other determinants of labor productivity growth, in particular characteristics of the institutional settings within the 13 EU economies, rows 11–19 include a range of policy variables. The magnitude of the coefficient of intangible capital remains robust after the inclusion, thus none of the included policy variables is able to alter the relationship. Rows 20–22 alter the included Business Cycle (as after a downturn in the economy, unemployment usually starts to rise with a lagged effect), incorporate eight-year dummies, and add an additional crisis dummy for the year 2000. Using a forward lagged business cycle in row 20 does not alter the coefficient. The eight-year dummies or an additional crisis dummy for the year 2000, are only able to alter the significance of the coefficient partially (to the 95 percent level), but tend to reduce its size to 0.22. When utilizing a jackknife post-estimation command (Stata Corporation, 2007, p. 22) in row 23, the coefficient is also around 0.22. A coefficient of 0.22 would still represent an impact of 39 percent on labor productivity growth.

8. Conclusion

Using new international comparable panel data on business intangible capital investment within a panel analysis from 1998–2005 in an EU country sample, the paper detects a positive and significant relationship between business investments in intangible capital and labor productivity growth within the business sector. Five findings emerge. First, the empirical analysis confirms the view that intangible capital investment is able to explain a significant portion of the unexplained international variance in labor productivity growth, and becomes the dominant source of growth of labor productivity. Second, this result is robust to a range of alterations and holds when controlling for endogeneity. The result is stronger in Mediterranean and Coordinated countries and within the time period 1998–2001. Third, the empirical analysis confirms the finding that the inclusion of intangible

[27]For the classification of the different regime typologies, see Hall and Soskice (2001). In contrast to Hall and Soskice, France was included in the coordinated cases and Scandinavian and transition countries were grouped into individual regime typologies. As the number of observations reach observation numbers as small as 16, which are below standard statistical reasoning, the results for the regime typologies should be considered as economically significant (McCloskey and Ziliak, 1996).

capital investment in the asset boundary of the national accounting framework implies that the rate of change of output per worker increases more rapidly. Fourth, the empirical analysis demonstrates that when incorporating intangibles into the national accounting framework, tangible and intangible capital become the unambiguously dominant source of growth. Fifth, the most important intangible capital dimension seems to be the dimension of economic competencies. Innovative property and software do not seem to have an impact on labor productivity growth within the given research design of the paper.

In light of these five points, three main policy conclusions should be drawn from our analysis of European economies. First, measuring innovation by solely focusing on R&D as it is currently proposed in the European 2020 agenda seems to be problematic, and the R&D benchmark measure should be substituted by a wider intangible capital benchmark. Second, incorporating intangible capital into today's national accounting framework seems to be necessary as developed economies transition into knowledge societies and thus the significant change of investment from tangible to intangible investment is not acknowledged in today's national accounting framework. The current accounting framework seems to be inaccurate as it incorrectly depicts levels of capital investment within European economies that are too low. In reality, European economies' levels of capital investment are significantly greater once incorporating investment in intangible capital. Third, incorporating a wider dimension of innovation investments seems to be a first important step in revising today's national accounting framework, in particular when focusing on the business sector. In addition, a next step seems to involve the wider adaptation of the national accounting framework by environmental, educational, health, and social capital.[28] Moreover, wider reform of the national accounting framework should be envisaged to achieve a more accurate signaling of real economic performance, to allow developed and emerging countries to strive for sustainable economic growth.

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[28]See the report by Stiglitz *et al.* (2009), for example.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix A1: Descriptive Statistics
Appendix A2: Construction of Intangible and Tangible Capital Services