INNODRIVE WORKING PAPER SERIES

Does intangible capital affect economic growth?

Felix Roth
Anna-Elisabeth Thum

May 2011

INNODRIVE Working Paper No 3

The research leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement n° 214576

Does intangible capital affect economic growth?

Felix Roth

Anna-Elisabeth Thum*

Abstract

Using new international comparable data on intangible capital investment by business within a panel analysis from 1995-2005 in an EU-15 country sample, we detect a positive and significant relationship between intangible capital investment by business and labour productivity growth. This relationship is cross-sectional in nature and proves to be robust to a range of alterations. Our empirical analysis confirms previous findings that the inclusion of business intangible capital investment into the asset boundary of the national accounting framework increases the rate of change of output per worker more rapidly. In addition, intangible capital is able to explain a significant portion of the unexplained international variance in labour productivity growth and when incorporating business intangibles, capital deepening becomes an even more significant source of growth. The relationship is slightly stronger in the time period 1995-2000 and seems to be driven by the coordinated countries within the EU-15.

* Dr. Felix Roth, Centre for European Policy Studies, Place du Congrès 1, 1000 Brussels, Belgium and Ibero-Amerika Institut, Oecinomicum II/99, Platz der Göttinger Sieben 3, 37073 Göttingen, Germany; Anna-Elisabeth Thum, Centre for European Policy Studies, Place du Congrès 1, 1000 Brussels, Belgium and European University Institute, Department of Economics, Via della Piazzuola 43, 50133 Firenze, Italy; E-mail: felix.roth@ceps.eu

The authors are grateful for a grant from the European Commission under the Seventh Framework Programme for the INNODRIVE project (Intangible Capital and Innovations: Drivers of Growth and Location in the EU, contract number 214576). This paper was produced as the CEPS Deliverable in WP9 and as part of the Seventh Framework Programme FP SSH 2007 1. We would also like to thank Massimiliano Iommi, Cecilia Jona-Lasinio and Stefano Manzocchi for their contribution of the variables on intangible capital.

1. Introduction

As highly developed economies are transforming more and more into knowledge economies, the input of intangible capital has become vital for the future competitiveness of their economies (Corrado, Hulten and Sichel 2005; World Bank 2006), as well as the competitiveness of their firms (Teece 1998, Youndt, Subramaniam and Snell 2004; Subramaniam and Youndt 2005; Lev and Radhakrishnan 2003 and 2005; Eustace 2000: 6). Although a further refinement of the concept of intangible capital is still clearly needed, the overall measurement of the different 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 (Sen, Fitoussi and Stiglitz 2009) and which dimensions should be included in a definition of intangible capital (World Bank 2006).

This paper focuses on intangible capital investment by business. Using international comparable data on business intangible capital investment generated within the INNODRIVE project, the paper tries to shed first econometric evidence on the impact of investments in business intangible capital on labour productivity growth. As envisaged in the INNODRIVE framework (Jona-Lasinio, Iommi and Roth 2009), the dimensions of business intangible capital were generated along the framework originally proposed by

[1] As recently as 1999, Robert Solow criticises 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* [highlighted by the author], solid, often durable things such as buildings, machinery, and inventories" (Solow 1999: 6). Ten years and one financial crisis later, the concept of *intangible capital* (including social and human capital) seems to have found its way into the economic discipline. The pure fact that the European Commission has financed three projects in the first round of its FP7 research grants on intangible capital and three more projects in the second round of its FP7 research grant underlines the new attention paid to the concept of intangible capital in economics. 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 generalised 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.

Corrado, Hulten and Sichel (2005 and 2006). However, as the authors deeply share the view of the World Bank (2006), that the dimensions of human and social capital should also be classified as intangible capital, the dimension of human capital has been included in the core model of the paper and the concept of social capital within the control variables.

2. Theoretical links between business intangible capital and labour productivity growth

It is widely recognised that knowledge and intellectual capital are major determinants of the generation of innovation and thus the enhancement of growth, employment and competitiveness of the European Union. 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 and Development has already been widely acknowledged – by policy makers and in economic theory – our knowledge of the contribution of business intangibles to labour productivity growth is still incomplete.

Economic theory has not completely discarded the importance of innovation. Actually, the inclusion of technological progress in models of economic growth started already with the Solow (1956) model, which is based on a production function with technological progress entering multiplicatively and as a constant. Later technological progress was allowed to grow over time, which implied different conclusions than the basic Solow model. In a further step technological progress was endogenised as in the Romer (1990) model. This theoretical model takes account of the fact that technological progress is driven by innovation and inventions by highly educated people. Endogenous growth models were further developed by Rebelo (1991), Grossman and Helpman (1991, 1994) and Aghion and Howitt (1992). However, in the empirical applications of these models technological change usually enters in these models econometrically as the error term and is not accounted for by an explicit empirical measure.

Generating a wider concept for innovation and focusing on the issue of a possible revision of the national accounting framework, Corrado, Hulten and Sichel (2005) have grouped the various items that constitute the knowledge of the firm into three basic categories: i) computerised information, ii) innovative property and iii) economic competencies. Whereas computerised information is embedded in computer programmes and computerised databases, innovative property reflects the scientific knowledge embedded in patents, licenses and general know-how (Corrado, Hulten and Sichel 2005: 26). Corrado, Hulten and Sichel (2005: 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 comprises expenditures on advertising, market research, firm-specific human capital and organisational change. 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 Corrado, Hao, Hulten and van Ark (2009: 63) stress, that products and services are becoming more knowledge-intensive.

While the positive relationship between computerised information, here in particular via an interaction effect with organisational capital, and innovative property on labour productivity growth has already been discussed extensively (Brynjolfsson, Hitt and Yang 2002; Khan and Luintel 2006), it seems to be important to once more stress the importance of the single dimensions of economic competencies, namely brand names, firm-specific human capital and organisational capital. Stressing why the single intangible capital dimensions should be accounted as gross fixed capital investment, has already been elaborated upon by Jona-Lasinio, Iommi and Roth (2009).[2] Further theoretical reasoning why the single dimensions of business intangible capital investments contribute to labour productivity growth can be given as follows.

---

[2] The expenditures as GFCF were classified according to the following principles: i) if the asset is identifiable – in other words, if it is separable (capable of being separated and sold, transferred, licensed, rented or exchanged, either individually or as part of a package); ii) if it is possible to identify the owner of the asset or who owns the intellectual property; iii) if the asset produces economic benefits for its owner; and iv) if the asset is used in the production process over several time periods. In particular, it is expected that the asset will provide capital services for over a year in the production of different products. Appendix 4 shows examples of the application of the four criteria to i) advertising, ii) market research and iii) scientific R&D as depicted by Jona-Lasinio, Iommi and Roth (2009).

In theory, *Brand Names* should positively affect labour productivity growth since an important aspect of today's products is the 'image' attached to them. Cañibano, Garcia-Ayuso and Sanchez (2000) argue that the ownership of a brand that is attractive to customers allows a seller to obtain a higher margin for goods or services that are similar to those provided by competitors. The authors refer to an analysis of Comanor and Wilson (1967) who were the first to provide early evidence on the usefulness of advertising. Not only does advertising strengthen the brand equity of a firm or customer loyalty, but it also has a positive effect on future stock performance and impacts positively actual and potential customers. In other words, expenditure on advertising is intended to create a perceived 'image' of the firm in the minds of potential consumers. As the consumer's choice among the products of competing firms is often driven by a perception of reliability and trustworthiness, the development of this image or brand has to be considered key in the yield of future benefits. Expenditure on market research constitutes, next to expenditure on advertising, an important part of the investment in brand equity. Both investments in advertising and market research comply with the four principles of categorising gross fixed capital formation, as can be seen in Appendix 4.

Firm-specific human capital

Firm-specific human capital is another important asset of a firm. In accordance with the findings of Huselid (1999) or Hand (1998), a firm with more capable employees is likely to earn higher profits than competitors whose workers have lower capabilities for the development of the tasks involved in the activity carried out by the firm (Cañibano, Garcia-Ayuso and Sanchez 2000). Thus, the value of companies will increase if the quality of their human resources increases (see also Abowd 2005).

Organisational capital

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 organisational capital of a firm becomes crucial. Lev and Radhakrishnan (2005: 75) define organisational 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”. Organisational capital is seen by many scholars (Teece, 1998; Youndt, Subramaniam and Snell 2004; Subramaniam and Youndt 2005; Lev and Radhakrishnan 2003 and 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 (information technologies and human capital). Leana and van Buren (2000) come up with the very interesting notion of organisational social capital and argue that the erosion of organisational social capital is diametrically opposed to the long-term competitiveness of the US and the long-term stability of individuals and society as a whole. They put forward three different aspects why low organisational capital might hamper a firm’s output: i) employees are more committed to their particular work than to the organisations for which they work, ii) flexible work organisation might be harder to achieve and iii) organisations are less able to solve collective action problems.

3. Previous empirical results

In the World Bank book entitled *Where is the wealth of nations? Measuring Capital for the 21st century*, researchers come to the conclusion that 78% of the world’s wealth is due to intangible capital (World Bank 2006: 24). Their results vary between developing and developed countries. Whereas in developing nations intangible capital is only responsible for 59% of the wealth, in OECD (high-income) countries the intangible capital share is 80%.

There are several empirical studies that try to estimate the importance of intangible assets for economic growth. Two different types of methodologies are currently used in the empirical literature on the relationship between intangible capital and growth. One group of researchers uses growth accounting[3] to incorporate measures of intangible capital into a growth model, while another group follows a more

[3] See for example Barro and Sala-i-Martin (2004), chapter 10.

econometric path and employs growth regressions. Growth accounting yields estimates that indicate how much of the growth of a dependent variable is explained by the various independent variables. Additionally the reduction in unexplained variance when adding a certain independent variable can be determined. In contrast to the growth accounting exercise, the regression technique can be used in a cross-country context and non-monetary indicators such as policy variables may be included.

There is an extensive growth accounting literature studying intangible capital investment both on the micro (firm-level) and on the macro (national) level. Sichel (2008) shows that one of the most recent approaches to measure intangible capital is to measure the difference between a firm's market value and its tangible assets. Several micro studies by Brynjolfsson and Yang (1999) and by Brynjolfsson, Hitt and Yang (2002) follow this approach to analyse the relation between intangible investment and computers in the US. Webster (2000) adopts a similar approach using Australian micro data and finds that the ratio of intangible to total capital rose by 1.25% a year from 1948 to 1998. Another definition is employed by Cummins (2005) who defines intangible capital in terms of adjustment costs and uses US firm-level data to estimate these costs. Lev and Radhakrishnan (2005) construct yet another measure of intangible capital using "sales, general and administrative expenses" as a proxy for organisational capital.

As this analysis conducts a cross-section and panel analysis taking the EU-15 countries as units of observations, it is particularly interested in analyses at the macroeconomic level.

In the first instance, there are several papers that measure the size of intangible capital stock as a percentage of GDP. Table 1 shows the most prominent results. Corrado, Hulten and Sichel (2005) find for the United States that the investment in intangibles was 12% of GDP between 1998 and 2000. Giorgio Marrano and Haskel (2006) show that in the United Kingdom the private sector spent a sum equivalent to 11% of GDP on intangibles in 2004[4]. Jalava, Aulin-Ahmavaara and Alenen (2007) find that the Finnish investment in intangibles was 9.1% of GDP in 2005. Fukao, Hamagata, Miyagawa and Tonogi (2007) estimate 7.5% of GDP as invested in intangible capital in Japan in 1995-

[4] Giorgio Marrano, Haskel and Wallis (2007) estimate that expenditure on intangibles amounts to 14% of GDP.

2002. Hao, Manole and van Ark (2008) study the spending as a share of GDP on intangible capital for Germany, France, Italy and Spain and find that Italy and Spain invested 5.2%, Germany 7.1% and France 8.8%. Van Rooijen, van den Bergen and Tanriseven (2008) find 10% for the Netherlands in 2001-2004. Edquist (2009) follows a similar approach and finds that in Sweden total spending on intangibles was equivalent to 10.6 % of GDP in 2004. Nakamura (2010) estimates spending in the United States from 1959 to 2007 and finds that investment in intangible capital is as important as investment in tangibles in the United States.

Table 1. Results on the importance of spending on intangibles

	Corrado,Hulten, Sichel (2005)	Marrano,Haskel (2006)	Jalava, Aulin-Ahmavaara, Alanen (2007)	Fukao, Hamagata, Miyagawa, Tonogi (2007)	Hao,Manole, van Ark (2008)	van Rooijen-Horsten, van den Bergen, Tanriseven (2008)	Edquist (2009)	Nakamura (2009)
Year	2003*	2004	2005	1995-2002	2004	2001-2004	2004	1959-2007
Countries studied	USA	UK	FIN	JAP	D,FR,I,ES	NL	SE	USA
Dependent variable	% of GDP	% of GDP	% of GDP	% of GDP	% of GDP	% of GDP	% of GDP	% of GDP
Spending on intangible capital as % of GDP	12.1%	10.1%	9.1%	7.5%	7.1% in D, 8.8% in FR, 5.2% in I,5.2% in ES	10.0%	10.6%	as important as investment in tangible assets

*Corrado, Hulten and Sichel (2005) report the number from 1998-2000. Hao, Manole and van Ark (2008) requested the estimate for 2003 from them.

Second, Corrado, Hulten and Sichel (2006) take these analyses a step further and develop a methodology to estimate the contribution of intangible capital to economic growth using a growth accounting framework. Table 2 shows an overview of some recent growth accounting studies on the effect of intangible capital on GDP growth for different countries and different time periods. Corrado, Hulten and Sichel (2006) find for the United States that 26% of labour productivity growth in 1973-1995 and 27% of labour productivity growth in 1995-2005 are explained by intangible capital. Growth increases by 20% in 1973-1995 and by 11% in 1995-2005 by adding intangible capital to the model. The unexplained variance in their model – in the literature referred to as "multifactor productivity" – decreases in importance from 51% to 35% in 1995-2005.

Marrano, Haskel and Wallis (2007) apply the methodology of Corrado, Hulten and Sichel (2006) to the United Kingdom and find that 15% of labour productivity growth is accounted for by intangible capital deepening in 1979-2005 and 20% in 1995-2003. Growth increases by 11% in 1973-1995 and by 13% in 1995-2003 when adding intangible capital investment to the asset boundary. Multifactor productivity declines from 22% to 16% when adding intangible capital. Jalava, Aulin-Ahmavaara and Alanen (2007) conduct a similar growth accounting exercise for Finland and find that intangible capital increases in importance after 2000. They find that intangible capital accounts for 16% of labour productivity growth in 1995-2000 and for 30% in 2000-2005. An increase in importance of intangible capital over time seems to hold also for Japan as Fukao, Hamagata, Miyagwa and Tonogi (2007) show. They find that intangible capital explains 11% of the Japanese growth rate in 1980-1990 and 40% in 1990-2002. They find further that adding intangible capital to the model increases growth by 3% in 1980-1990 and by 7% in 1990-2002. The authors show that adding intangible capital to the model causes the importance of multifactor productivity to decline. Hao, Manole and van Ark (2008) study Germany, France, Italy and Spain for the period 1995-2003. They find that intangible capital deepening accounts for 31% of labour productivity growth in Germany, 37% in France, 59% in Italy and 64% in Spain. Growth increases by 10% in Germany, 14% in France, 37% in Italy and 40% in Spain. In some quite recent work, Corrado, Hao, Hulten and Van Ark (2009) conduct a growth accounting exercise for several countries independently for 1995-2006, including the United States and selected EU-27 countries and on average over EU-15 countries. Similar to the findings of Corrado, Hulten and Sichel (2006) Corrado, Hao, Hulten and Van Ark (2009) find that intangible capital accounts for 28% of labour market productivity growth in the US. In the European countries intangible capital seems to be slightly less important than in the US, as their results shown in Table 1 indicate. In Germany, France, Italy, Spain, Austria and Denmark, intangible capital accounts for about 22% of labour productivity growth. All recent growth accounting studies find a positive effect of intangible capital on various measures of economic growth in different countries and for different time periods.

Table 2. Results in the growth accounting literature

	Corrado, Hulten, Sichel (2006)	Marrano, Haskel, Wallis (2007)	Jalava, Aulin-Ahmavaara, Alanen (2007)	Fukao, Hamagata, Miyagawa, Tonogi (2007)	Hao, Manole, van Ark (2008)	Corrado, Hao, Hulten, van Ark (2009)	Corrado, Hao, Hulten, van Ark (2009)	Corrado, Hao, Hulten, van Ark (2009)	Corrado, Hao, Hulten, van Ark (2009)	Corrado, Hao, Hulten, van Ark (2009)
Period studied	1973-1995; 1995-2003	1979-1995; 1995-2003	1975-2000; 2000-2005	1980-1990; 1990-2002	1995-2003	1995-2006	1995-2006	1995-2006	1995-2006	1995-2006
Countries studied	USA	USA & UK	FIN	JAP	D,F,I,ES	USA	UK	F	D	D,F,I,ES,AT, DK
Dependent variable	Labour productivity growth in the nonfarm business sector	Annual change in labour productivity in the nonfarm business sector	Labour productivity growth in the non-financial business sector	Growth rate of GDP	Growth of labour productivity in the market sector	Labour productivity growth in the market sector	Labour productivity growth in the market sector	Labour productivity growth in the market sector	Labour productivity growth in the market sector	Labour productivity growth in the market sector
% of dependent variable accounted for by intangible capital deepening	26% in 1973-1995, 27% in 1995-2003	26% in 1979-1995,27% in 1995-2003 in the US,15% in 1979-1995,20% in 1995-2003 in the US	16% in 1995-2000, 30% in 2000-2005	11% in 1980-1990, 40% in 1990-2002	31% in D,37% in F,59% in I,64% in ES	28%	23%	24%	21%	22%
Percentage points of dependent variable accounted for by intangible capital deepening	0.43 in 1973-1995, 0.84 in 1995-2003	0.43 in 1979-1995, 0.84 in 1995-2003 in the US; 0.44 in 1979-1995,0.60 in 1995-2003 in the UK	0.64 in 1995-2000, 0.84 in 2000-2005	0.43 in 1980-1990, 0.45 in 1990-2002	0.9 in F,0.6 in D, 0.4 in I, 0.2 in ES	0.83	0.69	0.48	0.38	0.3
Increase in growth by adding intangible capital to the asset boundary	20% in 1973-1995, 11% in 1995-2003	20% in 1973-1995, 11% in 1995-2003; 11% in 1973-1995, 13% in 1995-2003 in the UK	13% in 1995-2000, 2% in 1995-2005	3% in 1980-1990, 7% in 1990-2002	10% in D, 14% in F,37% in I,40% in ES	7%	6%	9%	12%	12%
Decrease in the importance of multifactor productivity when adding intangible capital deepening	Declines from 51% to 35% in 1995-2003	Declines from 51% to 35% in 1995-2003 in the US and from 22% to 16% in 1995-2003 in the UK	Declines from 59% to 42% in 1995-2005	Declines from 21% to 15% in 1980-1990 and from 10% to -5% in 1990-2002	Declines from 38% to 21% in D, from 44% to 23% in F	Declines from 64% to 45%	Declines from 53% to 40%	Declines from 48% to 35%	Declines from 61% to 49%	Declines from 31% to 21%

Third, we also found a vast body of empirical literature studying the relationship between R&D and economic growth using the growth regression approach. Most growth regression results, as shown in Table 3, also provide evidence of a positive effect of R&D on economic growth. There are studies on the micro or firm level as well as macro studies examining the country level. In our study we focus on the latter. Lichtenberg (1993) was the first to show empirically that R&D drives productivity at the aggregate or national level in addition to the firm and industry levels. He showed this by means of a 53-country cross-section regression. He finds that the elasticity of output with respect to private R&D is roughly 7% or about 1/3 as large as the elasticity of output with respect to physical capital. Indeed, the estimated social or national rate of return to private R&D is some seven times as large as the return to investment from physical capital.

Coe and Helpman (1995) show the extent to which a country's productivity depends on domestic *and* foreign R&D capital stocks. Using pooled macroeconomic data for 21 OECD countries plus Israel over the period 1971-1990, their results show that there is a close relationship between productivity and R&D capital stocks both domestic and foreign. Specifically, they show that the elasticity of total factor productivity with respect to domestic R&D, G7 domestic R&D, and foreign R&D is 0.073, 0.159 and 0.273, respectively. Coe and Helpman conclude that the estimated R&D spillover elasticities are large. Their study is significant in that it was one of the first to show empirically that a country's total factor productivity depends on its own R&D capital stock and the R&D capital stock of its trade partners.

Park (1995) examines the extent to which national R&D investments generate international knowledge spillovers using a panel dataset of ten OECD countries over the period 1970-1987. He is concerned to show three different sets of results: 1) the effects of public and private R&D on productivity growth, 2) the effects of international knowledge spillovers into production, and 3) the effects of international knowledge spillovers into research. He presents OLS, fixed effects and random effects estimates of the standard growth accounting equation with measures of domestic public and private R&D investment and physical capital as explanatory variables. Park's results indicate that international knowledge spillovers are asymmetrical: foreign private R&D spillovers go from the bigger to the smaller countries but not vice-versa. Given that the big countries such as the US, Japan and Germany undertake the bulk of research, the smaller countries tend to receive more foreign knowledge spillovers than they generate and, conversely, the bigger countries tend to generate more foreign knowledge spillovers than they receive.

In Table 3 we focus on very recent cross-country macro studies. Most studies use the stocks of R&D expenditure as a measure of R&D and several studies distinguish stocks of business, private and foreign R&D expenditure. O'Mahony and Vecchi (2003) use information and communication technology (ICT) capital as a measure of innovation. They find a positive and significant effect of ICT capital on growth of real output.

Kahn and Lunitel (2006) conduct an estimation allowing for cross-country heterogeneity and find that the three types of R&D – business, public and foreign – have a positive and significant effect on multifactor productivity growth in all 16 OECD countries in their sample. Bassanini and Scarpetta (2001) confirm this finding for the effect of business R&D on growth of GDP per capita when using the whole sample of 16 OECD countries and not taking into account the potential cross-country heterogeneity. However for public R&D expenditure they find a negative effect on growth. Guellec and Van Pottelsberghe (2001) also study a sample of 16 OECD countries but use yet another estimation method. They find the same positive and significant coefficient for business and public R&D expenditure but a slightly larger effect of foreign R&D on multifactor productivity growth.

Griffith, Redding and van Reenen (2004) study a two-fold effect of R&D on total factor productivity – firstly, the direct effect of R&D on total factor productivity and secondly the potential of R&D to increase the ability of an economy to absorb new technologies. Their sample includes only 12 OECD countries and the time period is slightly shorter. The measure they use for R&D is R&D expenditure as a percentage of GDP. To estimate their model the authors use a least squares dummy variable estimator and find a larger effect than the previously mentioned authors.

Table 3. Recent results for R&D or innovation and economic growth in cross-country growth regressions

	Kahn, Lunitel (2006)	Bassanini, Scarpetta (2001)	O'Mahony, Vecchi (2003)	Guellec, Van Pottelsberghe (2001)	Griffith, Redding, van Reenen (2004)
Period studied	1980-2002	1981-1998	1976-2000	1980-1998	1970-1992
Countries studied	16 OECD countries	16 OECD countries	55 separate sectors in the US and the UK	16 OECD countries	12 OECD countries
Dependent variable	Domestic multifactor productivity	GDP per capita growth	Growth of real output	Multifactor productivity growth	Total factor productivity growth
Estimation method	Heterogeneous dynamic panel (GMM)	Pooled mean group estimator	Pooled mean group estimator	Error correction model	Least squares dummy variable estimator, instrumental variables
Proxy for intangible capital	Stocks of real R&D expenditures by the foreign and domestic business sectors and domestic public sectors	Total (private and public) R&D expenditure (as a share of GDP)	ICT capital	Business, public and foreign R&D capital stocks	R&D expenditure as a percentage of GDP
Reported coefficients	0.027(business); 0.033(public); 0.010(foreign)	0.14 (total); 0.26 (business); -0.37 (public)	0.055 (total); 0.097 (USA); 0.053 (UK)	0.027 (business); 0.094 (foreign); 0.035 (public)	0.290-0.446 (depending on control variables)
Findings on the effect of R&D	Business, public and foreign R&D stocks augment productivity significantly in all 16 countries	A significant effect of R&D activity on the growth process; business R&D is positively associated with growth	A positive and significant effect of ICE growth on output growth; growth in ICT capital could account for about 40% of output growth	A positive and significant effect of R&D; elasticity of business R&D of 0.13	R&D affects TFP growth positively and significantly and increases the ability of an economy to absorb new technologies

This section has revised both previous empirical results from the growth accounting literature, as well as the growth regression literature. Both methodological approaches find a positive effect of intangible capital and R&D expenditure on economic growth.

The following analysis will combine the two methodologies and use a novel international comparable dataset on business investments in intangible capital for the EU-15 area.

4. Model specification, research design and data

4.1 Model specification

Our model specification takes into account both alternative methodologies to study the determinants of growth: growth regressions and growth accounting. The classical workhorse cross-country growth regression model has been developed by Mankiw, Romer and Weil (1992). This model is specified in terms of investment shares, which overcomes the difficulty of finding capital stock data. The assumption that all countries are in their steady state enables this specification. Barro (1991) proposed a more informal growth regression approach, in which the inclusion of variables is determined by previous findings. These models can be interpreted in terms of the Mankiw, Romer and Weil (1992) model since they typically include investment shares and initial income.[5]

Growth accounting models, on the other hand, are specified in terms of stock data or estimates of stock data. In this model specification the change in output is expressed in terms of changes in inputs. It is an empirical methodology in which the observed GDP growth is broken down into changes in factor inputs and in production technology. Growth accounting has several drawbacks with respect to growth regressions: firstly, it does not allow exploiting cross-country variation, which could be useful information for understanding the determinants of growth. Secondly, it does not aim to explain what determines growth and is seen more as a preliminary step towards a more fundamental analysis of the determinants of growth (see here Barro and Sala-i-Martin (2004): 433; Temple 1999: 121).

Benhabib and Spiegel (1994) and Temple (1999) propose a different model, which Temple calls “cross-country growth accounting” or “growth accounting with externalities”. This model combines both the growth accounting and the growth regression approach. In fact, the equation to be estimated is the same as the growth

[5] See Temple (1999), p. 124.

accounting equation but it is estimated using various methods of regression analysis. This methodology allows exploiting the cross-country variation in contrast to the growth accounting exercise.

We specify a model following Benhabib and Spiegel (1994) and extend it by including intangible capital and several other control variables. In our baseline model, labour productivity growth (GDP per hours worked) is dependent upon four input factors: physical capital K_{it}, human capital H_{it}, intangible capital I_{it} and hours worked N_{it}. The starting point for our estimation is a Cobb-Douglas production function, $Y_{it} = AK^{\alpha}_{it} H^{\beta}_{it} N^{\gamma}_{it}$. If we take log differences, the annual growth relationship can be expressed as:

$$\Delta \ln Y_{it} = \Delta A_{it} + \alpha \Delta \ln K_{it} + \beta \Delta \ln H_{it} + \gamma \Delta \ln I_{it} + \delta \Delta \ln N_{it} \quad (1)$$

Specifying equation (1) in terms of an econometric model yields:

$$\Delta \ln Y_{it} = \alpha_0 + \alpha \Delta \ln K_{it} + \beta \Delta \ln H_{it} + \gamma \Delta \ln I_{it} + \delta \Delta \ln N_{it} + w_{it} \quad (2)$$

where change in technological progress ΔA_{it} can be expressed as $\alpha_0 + w_{it}$.

We follow Benhabib and Spiegel (1994)[6] in their specification including also a lagged income term and in using the log of human capital levels. As mentioned above, since we are working with annual growth data rather than long term growth rates we need to add a control for business cycle fluctuations B_{it} (Guellec and van Pottelsberghe 2001). We add several ancillary variables X_{it}. A precise explanation for the theoretical reasoning behind which core and control variables were taken can be found in Appendix 2.

Following and trying to incorporate the growth accounting approach of Corrado, Hulten and Sichel (2006), we include intangible capital investment in the asset boundary and therefore also in the GDP variable. We denote this new GDP variable by Y^*_{it}.

[6] See section 4 “Growth accounting with human capital stocks entering into productivity” in Benhabib and Spiegel (1994).

The model we estimate then takes the form:

$$\Delta \ln Y^*_{it} = \alpha_0 + \eta Y_{it-1} + \alpha \Delta \ln K_{it} + \beta \Delta \ln H_{it} + \gamma \Delta \ln I_{it} + \delta \Delta \ln N_{it} + \mu\, B_{it} + \lambda X_{it} + w_{it} \quad (3)$$

4.2 Research design and data

Our analysis covers all 15 EU-15 countries for a time period from 1995-2005 with the overall number of observations being 150. The country sample is restricted to an EU-15 country sample and to a time period from 1995 to 2005 as it was not possible to extrapolate in the 12 new member states the investment in intangible capital far enough to validly construct stocks of business intangible capital. The fact that this was only possible for the 15 EU-15 countries determines our choice of only 15 countries. To estimate the best possible model, our data for our econometric analysis were taken from the various different data sources described below.

- Data on intangible capital were taken from the macro approach of the INNODRIVE project (Jona-Lasinio, Iommi Roth 2009). A detailed explanation of the data construction can be found in Appendix 3. Data on intangible capital investment and intangible capital stock cover solely the business investments for the sectors c-k + o. Our measure of business intangible capital includes R&D activities, product development in the financial service industry[7], market research, advertising, firm-specific human capital and organisational structure (own and purchased component).[8] As the available data are given in 1995 prices, in order to normalise the variable to 2000 prices we divide the intangible capital measure by the price deflator with base prices of 1995 and multiply by the price deflator with base prices of 2000.[9] The measure of intangible capital is adjusted by the purchasing power parity in 2000.

- The only database that would allow us to construct productivity data on a sectoral level would be EUKLEMS, but it misses important data on the capital stock for the five countries France, Belgium, Luxembourg, Portugal, Ireland and Greece. However, a preliminary country sample for a cross-section analysis with a

[7] In the light of the financial crisis it has become more doubtful whether it is feasible to treat the product development in the financial service industry as a valid intangible capital input.

[8] INNODRIVE team is especially thankful for the contribution by LUISS team members Massimiliano Iommi and Cecilia Jona-Lasino in their efforts to ensure the validity of the macro data.

[9] We use the price deflator for Gross Fixed Capital Formation available from the AMECO database.

European country sample should, at a minimum, hold information on an EU-15 country sample. We have therefore chosen to utilise the annual macroeconomic database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN), the AMECO dataset,[10] which contains information on capital stocks of all EU-15 countries. Furthermore, as this data cover the whole economy, the important policy-relevant question can be answered in how far business investment in intangible capital affects overall labour productivity growth in an economy. Annual labour productivity growth Y^*_{it} is specified as the growth of Gross Domestic Product per hour worked, adjusted by the purchasing power parity in 2000 and the 2000-based price deflator. The GDP measure already includes the intangible capital investment in mineral exploration, computer software and entertainment and literary or artistic originals. The physical capital indicator K_{it} is specified as the capital stock to which we applied the 2000-based price deflator as well as the 2000-based purchasing power parity.

- 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. This data are provided by Eurostat.

- Data on total hours worked were taken from DG ECFIN's AMECO database.

- Since we use annual data on growth we need to control for the business cycle influence. We include a proxy variable specified as 1-unemployment. This proxy is included as one of the ancillary variables X_{it} in the model.

- The data on the stocks of inward FDI, the stock market capitalisation, inflation, income taxes, government expenditure, education expenditure and social expenditure are taken from Eurostat.

- The data on openness to trade is retrieved from the Penn World Tables 6.2.

- The variables government efficiency and political stability are taken from Kaufmann, Kraay and Mastruzzi (2008). The World Bank (2006) uses these indicators as proxies for trust. Trust is a form of social capital. We therefore see the inclusion of these variables as adding a further measure of intangible capital to the model.

[10] One has to remark however that this research design comes with the price that tangible and intangible capital investments cannot be compared precisely as the tangible stock was generated for the whole economy and intangible capital stock was generated for business sector c-k+o. For consistency and robustness reasons we replicated all our econometric results with the 10 country case sample utilising productivity data on a sectoral level c-k + o. The econometric results did not differ significantly.

5. Descriptive analysis

Table A.1 in the Appendix shows the descriptive statistics of our data. The table shows the means over the EU-15 countries and over the time period 1995-2005. Annual labour productivity growth increases by 0.13 percentage points or by 6.7% when taking into account the contribution of intangibles in the measure of GDP. This number is comparable to the numbers reported by the studies listed in Table 2, which find that productivity growth increases by 12% in Germany, France, Italy, Spain, Austria and Denmark when adding intangible capital to the asset boundary. The reason why our number is smaller is that it measures the contribution of intangibles to the whole economy and not only to the business sector.

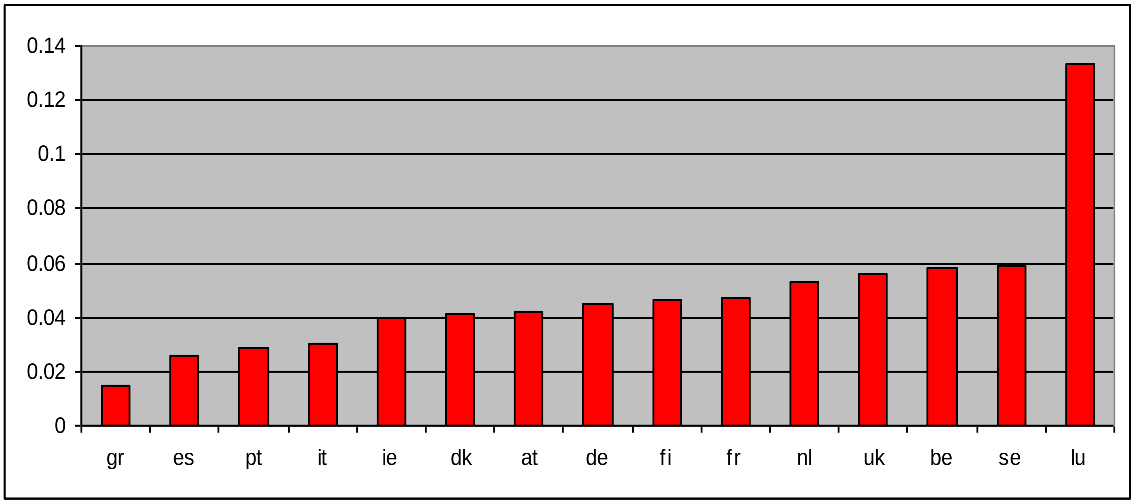
The descriptive results also show that the intangible capital stock grows on average at a faster rate than the physical capital stock. The growth rate of the intangible capital stock is 4.94, whereas the growth rate of the physical capital stock is 2.59. The mean physical capital stock is worth €1,582 million which is larger than the average intangible capital stock which is worth €64 million.

Business intangible capital investments differ strongly across the EU-15 countries. As shown in Figure 1, Luxembourg clearly outperforms the other European countries with a share of its investment in business intangible capital (which is mainly due to the development in new financial products) being 0.14 of GDP.[11] Luxembourg is followed by Sweden, Belgium and UK, all of which have a high level of intangible capital stock at around 6%.[12] The four Mediterranean countries Portugal, Italy, Spain and Greece are situated at the four last positions in the distribution. The largest European economy – Germany - is positioned in the middle of the distribution.

[11] The measure of GDP includes intangibles in the asset boundary.

[12] The levels of business intangible investment rates are lower than in Table 1 because it is the investment rate over the total economy.

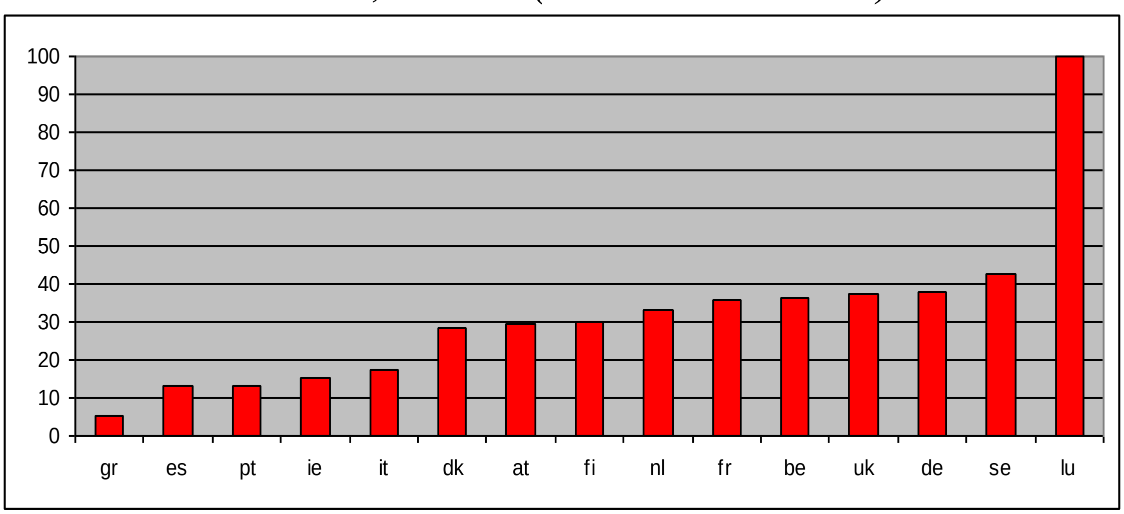
Figure 1. Level of intangible capital investment in the EU-15 countries, as a percentage of NEWGDP, 1995-2005



Note: The measure of intangible capital investment does not include data on ICT since ICT is already included in the GDP measure from the AMECO database.
Source: INNODRIVE database.

Figure 2 shows the average level of intangible capital stock from 1995 to 2005. Luxembourg again leads the distribution and is again followed by Sweden. Germany is positioned in third place. It has a better position in terms of business intangible capital stocks than it does in average investments from 1995-2005. Again the bottom part of the distribution is occupied by the four Mediterranean countries plus Ireland.

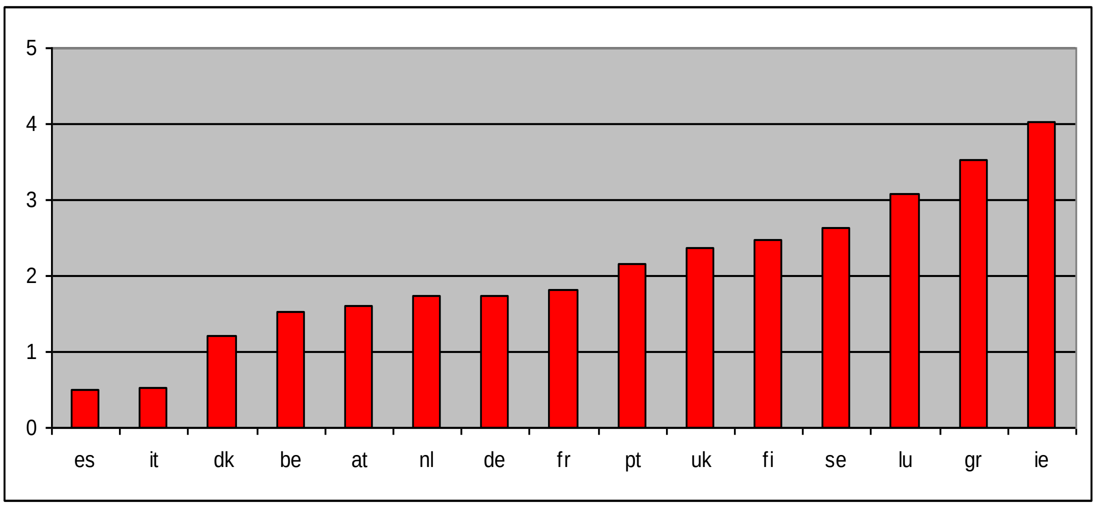
Figure 2. Level of intangible capital stock in the EU-15 countries, as a percentage of NEWGDP, 1995-2005 (normalised to a 100 scale)



Source: INNODRIVE database.

Figure 3 shows the growth rates of our measure of labour productivity. As outlined above and following the approach proposed by Corrado, Hulten and Sichel (2006), this measure already includes intangible capital investment. Ireland grows fastest followed by Greece at nearly 4%. This is surprising in the light of the previous findings that Greece occupies the lowest position in terms of intangible capital. Luxembourg holds the third position followed by Sweden, Finland and the UK. Germany and France are about in the middle of the distribution. Again Mediterranean countries – namely Italy and Spain, hold the lowest positions on the distribution, with growth rates lower than 1%.

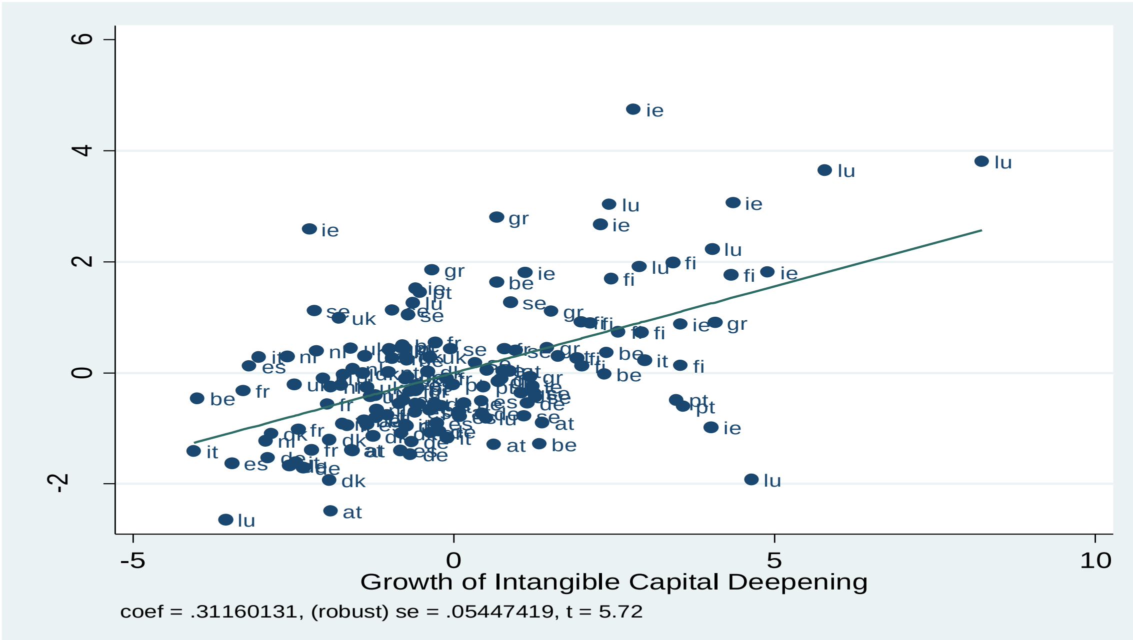
Figure 3. Growth rates of new labour productivity (GDP over hours worked, including intangible capital investment) in the EU-15 countries, average 1995 – 2005



Source: AMECO database and INNODRIVE data.

Figure 4 shows a partial regression plot between intangible capital deepening and labour productivity growth as specified in regression 2 (see Table 4). The graph clarifies that the growth of the stock of intangible capital is quite closely associated with the growth of labour productivity across the pooled country observations. The graph already visualises that the relationship will remain stable even with the exclusion of Luxembourg or any other country case.

Figure 4. Partial regression plot between intangible capital deepening and labour productivity growth – pooled cross-section estimation for the EU-15 countries



This finding is in sharp contrast to Figure 5, which shows a partial regression plot between intangible capital deepening and labour productivity growth controlling for country specific effects (thus, a fixed-effects estimation) as specified in regression 4 in Table 4. Showing an average over the effect within countries, the figure clarifies that the relationship between an increase of intangible capital and an increase of labour productivity within a country are positively but not robustly associated. The graph already illustrates that, after excluding the country case of Luxembourg, the relationship between intangible capital and labour productivity growth loses significance.

Figure 5. Partial regression plot between intangible capital deepening and labour productivity growth – fixed effects estimation for the EU-15 countries

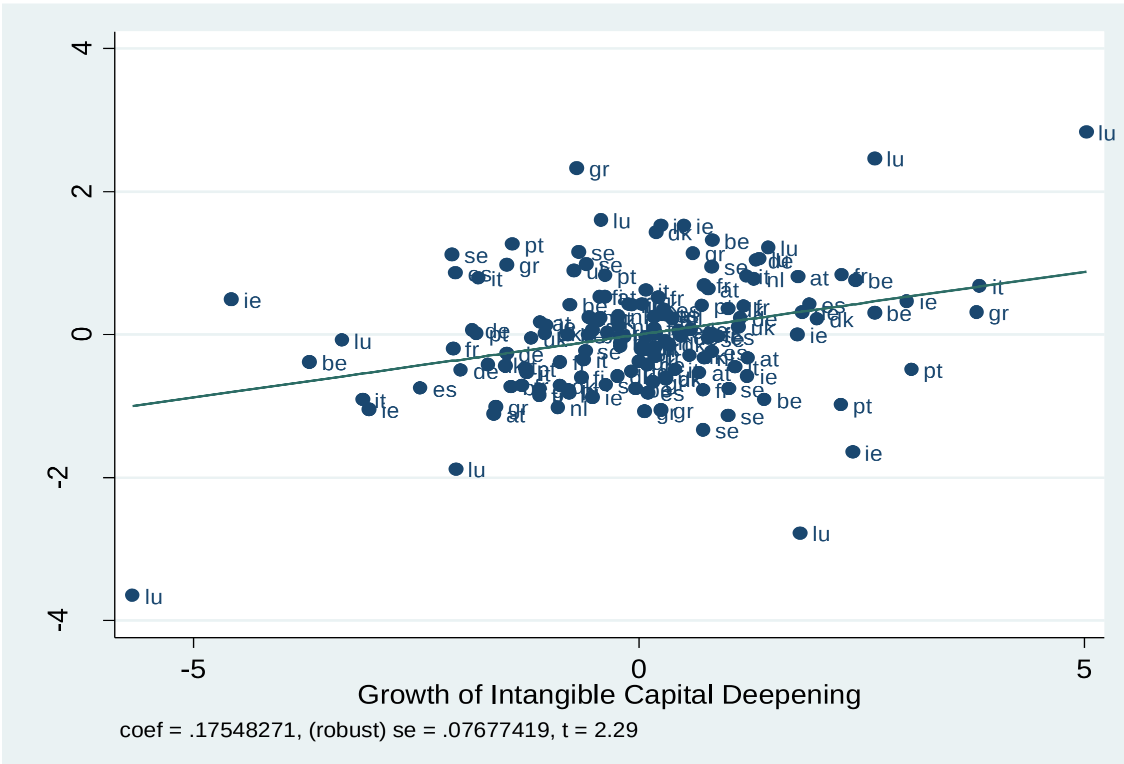
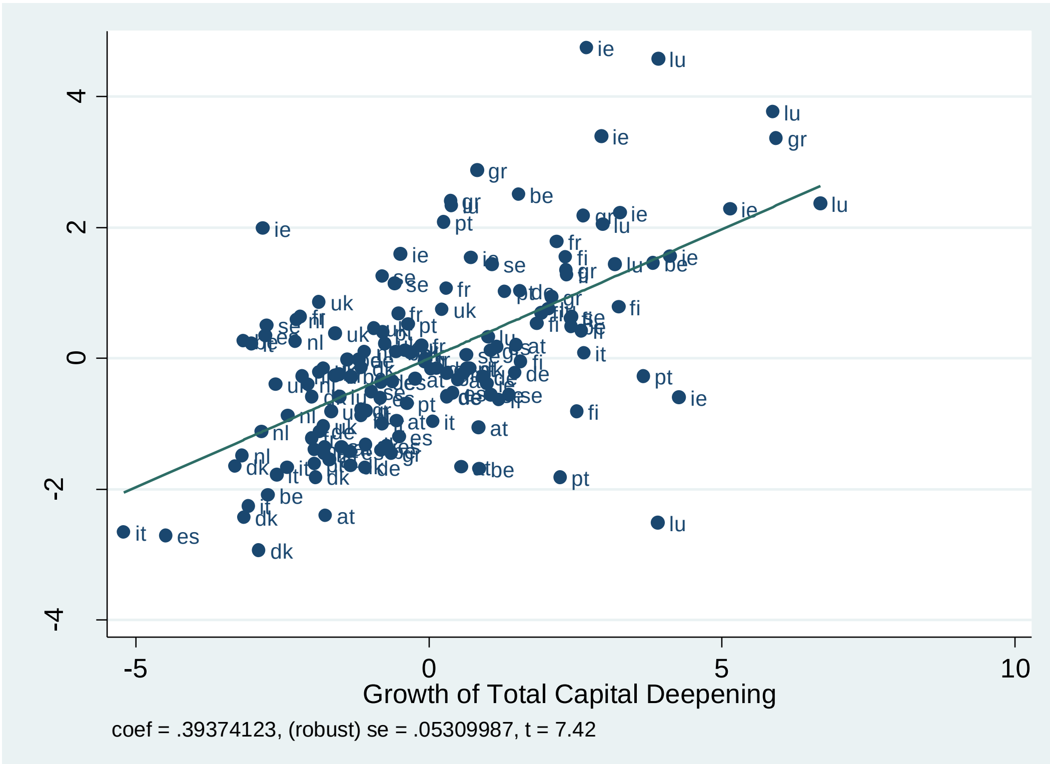


Figure 6 shows the relationship between the growth of our measures of both physical and intangible capital deepening, called 'total capital deepening', and the growth of labour productivity as specified in regression (4) in Table 6. The association is strongly positive and appears to be robust. In addition, it is stronger than the relationship between the growth of sole intangible capital deepening and labour productivity growth. Again, the graph already shows that the exclusion of Luxembourg or any other country will not change the significance of the effect. Thus, the positive relationship between total capital deepening (physical and intangible) and labour productivity seems robust.

Figure 6. Partial regression plot between total capital deepening and labour productivity growth – pooled cross-section estimation for the EU-15 countries



6. Econometric analysis

6.1 Growth regressions

Table 4 shows the results for ordinary least squares (OLS), fixed effects and random effects estimators for our model specification as depicted under section 4.1. Regression 1 shows the results when analysing the model using a traditional growth model only accounting for tangible capital. All coefficients have the appropriate signs. When analysing an EU-15 country sample over the time frame 1995-2005, we find conditional convergence (which will most likely be influenced by the cases of Ireland and Greece as already depicted in Figure 3), a negative coefficient for the input of labour, a positive coefficient for human capital and a positive input for the growth of physical capital stock. The proxy for business cycle is negative, which is consistent with the literature (Guellec and van Pottelsberghe 2001). 51% of the variation in the labour productivity growth can be explained by the model.

Table 4. Intangible capital and labour productivity growth – alternative estimation techniques

Estimation Method	OLS (1)	OLS (2)	FE (3)	FE (4)	RE (5)	RE (6)
Growth of Lagged Labour Productivity[a]	-2.641***	-1.569***	-8.938***	-10.32***	-2.882**	-1.752
	(0.575)	(0.578)	(2.844)	(2.887)	(1.262)	(1.068)
Growth of Hours Worked	-0.586***	-0.693***	-0.694***	-0.691***	-0.681***	-0.706***
	(0.0988)	(0.0847)	(0.104)	(0.0773)	(0.0945)	(0.0922)
Education	2.639***	1.948***	1.769	1.626	2.256***	1.903***
	(0.419)	(0.425)	(1.582)	(1.179)	(0.779)	(0.649)
Growth of Physical Capital Stock	0.891***	0.605***	0.607	0.645**	0.661***	0.581***
	(0.125)	(0.141)	(0.350)	(0.282)	(0.171)	(0.191)
Growth of Intangible Capital Stock		0.290***		0.190*		0.237***
		(0.0528)		(0.107)		(0.0707)
Proxy Business Cycle	-6.137*	-10.06***	-22.71**	-26.80***	-14.47**	-14.01***
	(3.343)	(3.083)	(9.762)	(7.617)	(6.408)	(5.123)
Constant	3.290	6.676**	45.34**	54.46***	15.55**	12.10**
	(3.168)	(2.777)	(16.12)	(10.06)	(6.820)	(4.951)
Observations	150	150	150	150	150	150
R-squared[b]	0.513	0.602	0.613	0.604	0.416	0.5749
Time effects	yes	yes	yes	yes	yes	yes
Number of countries	15	15	15	15	15	15

[a] Labour productivity augmented by investment in intangible capital if intangible capital stock included in the regression.

[b] The reported values for R squared are the overall value for the OLS and RE estimators and the within value for FE estimator.

Note: Robust standard errors are given in parentheses.

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

Regression 2 shows the results when including intangible capital into the asset boundary. The effect of conditional convergence becomes smaller (which already indicates that the input of intangible capital seems to be more important in the richer, more advanced EU-15 economies), the labour input gains some impact, the effect of education and physical capital becomes weaker and the growth of intangible capital stock is positively associated with labour productivity growth. The coefficient can be interpreted as follows: a 1% growth of intangible capital stock is associated with a 0.29 percentage points increase of labour productivity growth. The model is now able to explain 60% of variance, thus 9% more than when intangible capital is not included. Regression 3 shows a fixed-effects model when estimating a traditional growth model and taking only the tangible capital into account. We detect conditional convergence and a negative coefficient for the labour input. In model (4), growth of intangible capital stocks is incorporated. Intangible capital is positively related to labour productivity growth at the 90% significance-level. As can be easily referred from Figure 5, this positive relationship is mainly driven by the case of Luxembourg and once it is excluded from the analysed country sample, the relationship between intangible capital and productivity growth becomes insignificant. Thus one should conclude that an increase in the growth of intangible capital is not associated with an increase of labour productivity growth when considering only the within-country effect. Regressions 5 and 6 utilise a random effects model. Similarly to the OLS model, the regressions depict the cross-sectional effect[13] of intangible capital and labour productivity growth. As the between R-Squared value is significantly higher than the within R-Squared value there is some evidence that the model explains the between-country variation in labour productivity growth better than the within-country variation. The coefficient of 0.237 is slightly smaller than in the OLS model. In this model specification, the inclusion of intangible capital is now able to explain 16% more of the international variance within labour productivity growth.To be able to better compare our results with those from the growth accounting methodology in Table 2, Table 5 shows our model specification when including the concepts of capital and intangible capital deepening. Including intangible capital deepening in regression 2 gives similar results as seen in Table 1, Regression 2, 4 and 6. However, this time the inclusion of intangible capital increases the R-Squared by 12% in the OLS estimation and by 16% by the random effects specification. The figure of 16% is quite closely connected to various growth accounting results as depicted in Table 2. In their analysis of the five countries Germany, Finland, Denmark, Spain and Austria, Corrado, Hao, Hulten and Sichel (2009) conclude that the intangible capital deepening explains 22% of labour productivity growth. As the authors work with a smaller GDP measure related to the market sector and as we analyse the whole economy, our value of 16% seems to be adequate and in close range. The coefficients of intangible capital deepening are quite similar to those shown in Table 4. However, in the fixed-effects estimation the effect of intangible capital deepening becomes insignificant even with the inclusion of Luxembourg.

[13] To put it correctly the random effects estimator is a combination of a within- and a between-estimator. In our case the between variation is higher. This means that the significance of the intangible capital coefficient is driven by the between variation.

Table 5. Intangible capital deepening and labour productivity growth

Estimation Method	OLS (1)	OLS (2)	FE (3)	FE (4)	RE (5)	RE (6)
Growth of Lagged Labour Productivity[a]	-2.040***	-1.192**	-9.344***	-9.628***	-3.227**	-1.545
	(0.511)	(0.543)	(2.976)	(3.166)	(1.319)	(1.091)
Education	1.936***	1.477***	1.641	1.895	2.379***	1.658***
	(0.332)	(0.326)	(1.375)	(1.408)	(0.735)	(0.580)
Growth of Capital Deepening	0.662***	0.438***	0.683***	0.525***	0.679***	0.488***
	(0.0918)	(0.0949)	(0.130)	(0.152)	(0.0921)	(0.116)
Growth of Intangible Capital Deepening		0.312***		0.175		0.235***
		(0.0545)		(0.104)		(0.0703)
Proxy business cycle	-4.166	-9.440***	-23.54**	-25.09***	-16.21***	-13.00***
	(3.162)	(3.010)	(8.104)	(6.176)	(6.190)	(4.792)
Constant	4.338	7.190***	47.73***	49.91***	17.74**	10.40**
	(3.016)	(2.726)	(13.07)	(10.89)	(7.144)	(5.033)
Observations	150	150	150	150	150	150
R-squared[b]	0.472	0.587	0.612	0.602	0.4027	0.5607
Time effects	yes	yes	yes	yes	yes	yes
Number of countries	15	15	15	15	15	15

[a] Labour productivity augmented by investment in intangible capital if intangible capital stock included in the regression.

[b] The reported values for R squared are the overall value for the OLS and RE estimators and the within value for FE estimator.

Note: Robust standard errors are given in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

.

Table 6 tries to elaborate the findings by Corrado, Hulten and Sichel (2006) that once incorporating intangible capital as Gross Fixed Capital Formation, capital deepening becomes the dominant source of growth. Regression 1 in Table 6 shows a model including the lagged income term, education and the proxy for the business cycle. Once incorporating tangible capital deepening, the model is able to explain 22% more of the variance. Although this effect of tangible capital deepening is already quite strong, regression 4 shows that after the inclusion of intangible capital, to become total capital deepening, 28% more of the variance can be explained and thus total capital explains nearly a third of total percent to be explained (51%).

Table 6. Total Capital Deepening and Labour Productivity Growth

Estimation Method	OLS (1)	OLS (2)	OLS (3)	OLS (4)
Growth of Lagged Labour Productivity[a]	-2.590***	-2.040***	-1.578**	-1.578**
	(0.699)	(0.511)	(0.793)	(0.605)
Education	1.292***	1.936***	0.887**	1.101***
	(0.404)	(0.332)	(0.448)	(0.349)
Growth of Capital Deepening		0.662***		
		(0.0918)		
Growth of Total Capital Deepening				0.394***
				(0.0531)
Proxy business cycle	5.692	-4.166	8.710**	-5.802*
	(3.511)	(3.162)	(3.839)	(3.195)
Constant	0.0451	4.338	-4.110	7.624**
	(3.470)	(3.016)	(3.914)	(3.060)
Observations	150	150	150	150
Time effects	yes	yes	yes	yes
R-squared	0.252	0.472	0.226	0.509
Number of countries	15	15	15	15

[a] Labour productivity augmented by investment in intangible capital if intangible capital stock included in the regression.

Note: Robust standard errors are given in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

6.2 Dynamic panel analysis

Growth regressions usually present several econometric problems. Firstly, the right-hand side variables are usually endogenous. Secondly, the initial level of efficiency is unobserved and correlated with the lagged level of income. This results in an omitted variable bias. To address these issues Arellano and Bond (1991) have developed a – popular and frequently used, estimator using a Generalised Method of Moments methodology, the GMM difference estimator. The idea is to remove the country-specific time-invariant effects by taking first differences, to add a lagged income term and to instrument for the right-hand side variables. The instruments are specified as the levels of the lagged variables. The omitted variable bias stemming from unobserved country-specific effects is addressed by taking first differences, and the problem of endogeneity is addressed by using instruments. Necessary assumptions for this estimator are that the errors are serially uncorrelated and that the instruments do not over-identify the model.[14]

However, as highlighted by Bond, Hoeffler and Temple (2001), the GMM difference estimator has its own pitfalls, especially in econometric cross-country growth regressions. The authors show that the GMM difference estimator appears to be biased in the growth context. The reason is that the first-differenced estimator behaves poorly if the time series is persistent[15] and if the time dimension is small. If a time series is persistent, its lagged levels are weak instruments and their use can imply that the parameter estimates are biased in finite samples. According to Bond, Hoeffler and Temple (2001), growth models are usually characterised by a persistent income variable and by a small time dimension. They show that the GMM difference estimator is largely downward biased in their simulations. The estimate should lie between the upward biased OLS estimate and the downward biased fixed-effects estimate. In their simulation the difference estimate lies even below the downward biased fixed effects estimator.

To address these problems of weak instruments and a small time dimension, Bond, Hoeffler and Temple (2001) recommend using a more efficient estimator, the GMM system estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). This estimator is consistent even if the time series are persistent and has better finite sample properties as their simulations show.

Comparing the results of Tables 5 and 7 shows that the GMM difference estimate of the lagged dependent variable effect is close to the fixed effects estimate when not using time dummies and far below when using time dummies. This observation indicates that we should implement the GMM system estimator especially when working with time dummies. Table 7 shows the results when estimating our model with GMM difference and GMM system methodology[16]. After including intangible capital deepening growth in

[14] These assumptions are tested automatically in the implemented STATA command by Roodman (2000). Precisely, an AR(2) test of the error terms and a Sargan or Hansen test of over-identification are implemented.

[15] A time series is persistent when its values depend (strongly) on its past values. In this case the series is characterised by an AR(1) process such as a random walk.

[16] As shown in Bond, Hoeffler and Temple (2001:5), the assumptions made for the GMM difference estimator are (1) that the errors are not autocorrelated and that (2) the initial conditions y_{1i} are uncorrelated with the error terms (this assumption is implies that the instruments need to be exogenous). For the GMM system estimator an additional theoretical assumption is made (Bond, Hoeffler, Temple 2001:8): (3) the

regressions 2 and 4, we are able to replicate the results of our OLS, and random effects estimation. In contrast to our fixed-effects estimation in Regression 2, we get a positive relationship between intangible capital deepening growth and labour productivity growth. However, after excluding Luxembourg from the sample, the relationship becomes insignificant. The coefficient of intangible capital deepening growth is higher than with our OLS and random effects estimation. Remarkably, once incorporating intangible capital deepening in regression 4 the effect of conditional convergence loose significance and becomes weaker. In a next step we want to test the robustness of our result in Regression 4 in Table 7.

---

differences of the instrumenting variables are not correlated with the fixed effects (this assumption implies that the additional instruments need to be exogeneous).
The first assumption of no serial correlation can be tested using a test which is implemented in Roodman;s (2006) STATA command for GMM difference and system estimators. In our case, it gives evidence of no second order serial autocorrelation: the Null hypothesis of no serial autocorrelation is accepted for the GMM system estimator with a test statistic of 0.79 and a p-value of 0.432 and for the GMM difference estimator with a test statistic of 0.43 and a p-value of 0.665. The second assumption of the validity of the instruments can be tested by the Sargan or Hansen test for the joint validity of the moment conditions (Roodman, 2006: 13). When using the robust estimation procedure, the Hansen test should be used. In our case, the Hansen statistic is 0.13 with a p-value of 1.000, which indicates that we cannot reject the Null hypothesis of joint validity of the instruments. The third assumption – the validity of the additional instruments - can also be tested by using the Sargan or Hansen test (Band, Hoeffler, Temple 2001: 9). In our case, the Hansen statistic is 5.18 with a p-value of 1.000, which indicates that we cannot reject the Null hypothesis of joint validity of the instruments.
An additional problem we need to take into account is the issue of too many instruments (Roodman 2006:13). Too many instruments can cause overfitting of the endogeneous variables by the instruments and an unreliable Hansen test statistic. This problem arises when the number of instruments is so large that the number of equations is larger than the number of variables (Roodman, 2006: 3). In our case, this might be a problem since we have 15 countries and 10 time dimensions. As proposed by Roodman (2006:44) we therefore reduce the number of instruments by including only the second lag in the equations as instruments. A further robustness check in this case, is to collapse the number of instruments using the 'collapse' option. When implementing this procedure we obtain no significant changes in the main results.

Table 7. Intangible capital and labour productivity growth – dynamic panel estimation

Estimation Method	GMM diff (1)	GMM diff (2)	GMM sys (3)	GMM sys (4)
Lagged Labour Productivity[a]	-1.127	-13.99	-1.774*	-0.654
	(7.941)	(10.49)	(1.037)	(0.472)
Education	-2.153	-3.425	1.764**	1.189***
	(2.403)	(2.598)	(0.697)	(0.449)
Growth of Capital Deepening	0.776***	0.227*	0.686***	0.459***
	(0.131)	(0.122)	(0.138)	(0.117)
Growth of Intangible Capital Deepening		0.416***		0.330***
		(0.121)		(0.0731)
Proxy business cycle	-23.60	-2.514	-6.769	-15.08*
	(20.42)	(33.85)	(5.727)	(8.224)
Constant			5.485	11.44
			(5.702)	(7.849)
Observations	135	135	150	150
Time effects	yes	yes	yes	yes
Number of countries	15	15	15	15

[a] Labour productivity augmented by investment in intangible capital if intangible capital stock included in the regression.

Note: Robust standard errors are given in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

6.3 Sensitivity analysis

Table 8 shows a sensitivity analysis of regression 4 in Table 7. The first row, which is titled "none", depicts the coefficient of intangible capital deepening of regression 4 in Table 7. As can be depicted from Figures 4 and 5 Luxembourg and Ireland could be performing as outliers. Thus in row two of Table 8 we exclude Luxembourg from our sample. The relationship between intangible capital deepening and labour productivity growth becomes smaller with a coefficient of 0.193. But it remains significant at the 95%-level.

Table 8. Sensitivity analysis – the Arellano Bond system estimation

Row	Specification Change	Coefficient on Intangible Capital	Standard Error	Countries	Observations	Coefficint on the additional variable	R squared[b]
	Influential Cases						
(1)	None	0.330***	(0.0731)	15	150	-	0.5607
(2)	Out Luxemburg	0.193**	(0.0965)	14	140	-	0.5071
(3)	Out Ireland	0.285***	(0.0837)	14	140	-	0.6421
	Restructuring of data						
(4)	1995-2000	0.390***	(0.0873)	15	75	-	0.5696
(5)	2001-2005	0.319***	(0.101)	15	75	-	0.6134
	Restructuring of Country Sample						
(6)	Mediterranean	0.0854	(0.138)	4	40	-	0.8939
(7)	Coordinated	0.335***	(0.0935)	6	60	-	0.687
(8)	Scandinavian	-0.0370	(0.181)	3	30	-	0.8058
(9)	Liberal	-0.273	-	2	20	-	0.9735
	Specifications						
(9)	Stocks of inward FDI[a]	0.235***	(0.0853)	14	121	0.0164***	0.6284
(10)	Openness to trade	0.255***	(0.0639)	15	135	0.0149***	0.5231
(11)	Stock Market Capitalization in % of GDP	0.291***	(0.0467)	15	139	0.00651**	0.6209
(12)	Inflation	0.269***	(0.0565)	15	150	-0.162**	0.6094
(13)	Income tax in % of GDP	0.327***	(0.0670)	15	150	0.0104	0.5568
(14)	Government Efficiency	0.286**	(0.118)	15	105	0.442	0.6294
(15)	Political Stability	0.260**	(0.127)	15	105	0.977*	0.6265
(16)	Government Expenditure in % of GDP	0.254***	(0.0635)	15	150	-0.0710***	0.5904
(17)	Education Expenditure in % of GDP	0.295***	(0.0644)	15	150	-0.0574	0.5602
(18)	Social Expenditure in % of GDP	0.214***	(0.0754)	15	149	-0.133***	0.5981

[a] Data for Belgium is unavailable.

[b] The values for R squares are retrieved from a random effects regression (overall R squared).

Note: Robust standard errors are given in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

When excluding Ireland in row three, the relationship is still significant and the effect becomes slightly smaller. When restructuring the data in row 4 into the two time periods 1995-2000 and 2001 to 2005, we detect that the relationship seems to be slightly stronger in the time period from 1995 to 2000 (0.390) than from 2001-2005 (0.319). However, the relationship remains highly significant in both time periods.

In rows 6-9 we analyse which regime typology within the EU-15 countries might be driving the positive result. Interestingly, it seems that the coordinated countries (Germany, Austria, Belgium, Netherlands, Luxembourg and France) are driving the positive result between intangible capital deepening and labour productivity growth. Once excluding Luxembourg from the coordinated sample, the positive relationship remains highly significant. In the Scandinavian and ‘Liberal’ countries (see Hall and Soskice, 2001), the effect is even negative, although not significant.

Since labour productivity growth might be related to many other determinants of growth, here in particular characteristics of the institutional settings within the single EU-15 economies, rows 9 to 18 include a range of policy variables. As the magnitude of the coefficient of the single control variables is also relevant for the European economic policy process we have included it in the table. None of the ten included control variables is able to alter the relationship between business intangible capital deepening and labour productivity growth. Furthermore, none of the additional control variables is able to increase the R-Squared value significantly. Furthermore, we can conclude that stocks of inward FDI, openness to trade, stock market capitalisation in % of GDP are positively related to labour productivity growth when taking our model specification with the EU-15 from 1995 to 2005. Inflation, government expenditure and social expenditure as a % of GDP are negatively related to labour productivity growth. As mentioned above, we use government efficiency and political stability similar to the World Bank approach (2006) as proxies for social capital[17]. Government efficiency appears to have an insignificant effect, whereas political stability is positively and significantly related to labour productivity growth. Finally, education expenditure is not significantly related to labour productivity growth.

7. Conclusion

Using new international comparable data on business intangible capital investment within a cross-sectional and panel analysis from 1995-2005 in an EU-15 country sample we detect a positive and significant relationship between business investments in intangible capital and overall economic labour productivity growth.

First, this relationship is cross-sectional and proves to be robust to a range of alterations. The relationship is stronger in the time period 1995-2000 and in coordinated countries. The result indicates that a country with a high intangible capital deepening growth rate is associated with a higher labour productivity growth rate.

[17] As shown in Table A.1 in the Appendix, these indicators contain 50 missing values and the time series per country are not continuous.

Second, the relationship does not hold when controlling for country-specific effects, thus an increase of intangible capital deepening in a country is not associated with an increase of labour productivity growth in that country in the given time frame from 1995 to 2005.

Third, our empirical analysis confirms that the inclusion of intangible capital investment into the asset boundary of the national accounting framework implies that the rate of change of output per worker increases more rapidly.

Fourth, our empirical analysis confirms that intangible capital investment is able to explain a significant portion of the unexplained international variance in labour productivity growth, and thus diminishes the unexplained part of labour productivity growth, and hence a measure of our ignorance.

Fifth, our empirical analysis confirms, that when incorporating intangibles into the national accounting framework, capital deepening becomes more important.

In the light of these five points, what main policy conclusions can we draw from our empirical analysis for the European economies? Three main policy conclusions should be drawn from our analysis.

First, measuring innovation by solely focusing on R&D as it is currently proposed in the European 2020 agenda is not valid, 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 flawed as it incorrectly depicts too low levels of capital investment within European economies. In reality European economies' levels of capital investment are significantly larger once incorporating investment in intangible capital. Thus, policy conclusions based upon investment rates in 'bricks and mortars' should be handled with caution.

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.[18] Moreover, wider reform of the national accounting framework should be envisaged to achieve a more accurate signalling of real economic performance and allowing developed and emerging countries to strive for sustainable economic growth.

References

Abowd, J. (2005), "The Relationship Among Human Capital, Productivity and Market Value: Building Up from Micro Evidence", in C. Corrado, J. Haltiwanger and D. Sichel (eds), *Measuring Capital in the New Economy*, Chicago; IL: University of Chicago Press.

Aghion, P. and P. Howitt (1992), "A Model of Growth through Creative Destruction", *Econometrica*, Vol. 60, pp. 323-351.

Arellano, M. and S. Bond (1991), "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations", *Review of Economic Studies*, Vol. 58, pp. 277-297.

Arellano, M. and O. Bover (1995), "Another look at the instrumental variable estimation of error-components models", *Journal of Econometrics*, Vol. 68, pp. 29-51.

Bassanini, A. and S. Scarpetta (2002), "Does human capital matter for growth in OECD countries? A pooled mean-group approach", *Economic Letters*, Vol. 74, No. 3, pp. 399-405.

Barro, R. (1991), "Economic Growth in a Cross Section of Countries", *The Quarterly Journal of Economics*, 106 (2), pp. 407-443.

Barro, R. and X. Sala-i-Martin (2004), *Economic Growth*, 2nd edition, Cambridge, MA: MIT Press.

Benhabib, J. and M. Spiegel (1994), "The role of human capital in economic development – evidence from aggregate cross-country data", *Journal of Monetary Economics*, Vol. 34, pp. 143-173.

Blundell, R. and S. Bond (1998), "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, Vol. 87, pp. 115-143.

Bond, S., A. Hoeffler and J. Temple (2001), *GMM Estimation of Empirical Growth Models*, CEPR Discussion Paper No. 3048, Centre for Economic Policy Research, London.

[18] See here e.g. the report by Sen, Fitoussi and Stiglitz (2009).

Brynjolfsson, E. and S. Yang (1999), "The Intangible Costs and Benefits of Computer Investments: Evidence from the Financial Market", paper presented at the International Conference on Information Systems, Atlanta, Georgia, December 1997, revised May 1999.

Brynjolfsson, E., L.M. Hitt and S. Yang (2002), "Intangible Assets: Computers and Organizational Capital", *Brookings Papers on Economic Activity, 2002-1*, Brookings Institution, Washington, D.C., pp. 137-181.

Cañibano, L., M. Garcia-Ayuso and P. Sanchez (2000), "Accounting for Intangibles: A Literature Review", *Journal of Accounting Literature*, Vol. 19, pp. 102-130.

Coe, D. and E. Helpman (1995), *International R&D Spillovers*, NBER Working Paper No. 4444, National Bureau of Economic Research, Cambridge, MA.

Comanor, W.S. and T.A. Wilson (1967), "Advertising, market structure and performance", *Review of Economics and Statistics*, Vol. 49, pp. 423-440.

Corrado, C., C. Hulten and D. Sichel (2005), "Measuring Capital and Technology: An expanded framework", in C. Corrado, J. Haltiwanger and D. Sichel (eds), *Measuring Capital in the New Economy*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 65, Chicago, IL: University Chicago Press, pp. 11-45.

Corrado, C., C. Hulten and D. Sichel (2006), *Intangible Capital and Economic Growth*, NBER Working Paper No. 11948, National Bureau of Economic Research, Cambridge, MA.

Corrado, C., J.X. Hao, C. Hulten and B. van Ark (2009), "Measuring intangible capital and its contribution to economic growth in Europe", *European Investment Bank Papers*, Vol. 14, No. 1, pp. 63-93.

Cummins, J. (2005), "A new approach to the valuation of intangible capital", in C. Corrado, J. Haltiwanger and D. Sichel (eds), *Measuring Capital in the New Economy*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 65, Chicago: University Chicago Press, pp. 47-72.

Edquist, H. (2009), *How much does Sweden invest in intangible assets?*, IFN Working Paper Series No. 785, Research Institute of Industrial Economics, Stockholm.

European Commission (2010), "Europe 2020. A European strategy for smart sustainable and inclusive growth", Communication from the Commission, European Commission, Brussels.

Eustace, C. (2000), *The Intangible Economy Impact and Policy Issues*, Report of the European High Level Expert Group on the Intangible Economy, European Commission.

Fukao, K., S. Hamagata, T. Miyagawa and K. Tonogi (2007), *Intangible Investment in Japan: Measurement and Contribution to Economic Growth*, RIETI Discussion Paper No. 07-E-034, Research Institute of Economy, Trade and Industry, Tokyo.

Giorgio Marrano, M. and J. Haskel (2006), *How much does the UK invest in intangible assets?*, Department of Economics Working Paper No. 578, Queen Mary, University of London.

Giorgio Marrano, M., J. Haskel and G. Wallis (2007), *What happened to the knowledge economy? ICT, Intangible Investment and Britain's Productivity Record Revisited*, Department of Economics Working Paper No. 603, Queen Mary, University of London.

Griffith, R., S. Redding and J. Van Reenen (2004), "Mapping the two faces of R&D: Productivity Growth in a Panel of OECD Industries", *The Review of Economics and Statistics*, Cambridge, MA: MIT Press, Vol. 86, No. 4, pp. 883-895, December.

Grossman, G.M. and E. Helpman (1994), "Endogenous Innovation in the Theory of Growth", *Journal of Economic Perspectives*, Vol. 8, pp. 23-44.

Guellec, D. and B. van Pottelsberghe (2001), *R&D and productivity growth: panel data analysis of 16 OECD countries*, OECD Economic Studies No. 33, 2001/II, OECD, Paris.

Hall, P. and D. Soskice (eds) (2001), *Varieties of Capitalism*: *The Institutional Foundations of Comparative Advantage*, Oxford: Oxford University Press.

Hand, J. (1998), *Does CEO human capital make a difference?*, Working Paper, Rutgers University, New Brunswick, NJ.

Hao, J., V. Manole and B. van Ark (2008), *Intangible Capital and Growth – An International Comparison*, Economics Program Working Paper Series, EPWP No. 08-14, Conference Board Inc., New York, December.

Huselid, M. (1999), *Human resources, knowledge management and firm performance*, Working Paper, Rutgers University, New Brunswick, NJ.

Jalava, J., P. Aulin-Ahmavaara and A. Alanen (2007), *Intangible Capital in the Finnish Business Sector, 1975-2005*, ETLA Discussion Paper No. 1103, Research Institute of the Finnish Economy, Helsinki.

Jona-Lasinio, C., M. Iommi and F. Roth (2009), Report on data gathering and estimations for the INNODRIVE project – Macro approach (Deliverable No. 15, WP9).

Kaufmann, D., A. Kraay and M. Mastruzzi (2008), *Governance matters VII : aggregate and individual governance indicators 1996-2007*, Policy Research Working Paper Series, No. 4654, World Bank, Washington, D.C.

Khan, M. and K. Luintel (2006), *Sources of Knowledge and Productivity: How Robust is the Relationship?*, OECD Science, Technology and Industry Working Paper No. 2006/6, OECD, Directorate for Science, Technology and Industry, Paris.

Landes, E. and A. Rosenfield (1994), "The durability of advertising revisited", *Journal of Industrial Economics*, Vol. 42, pp. 236-276.

Leana, C. and H. van Buren (2000), "Eroding Organizational Social Capital among US Firms: The Price of Job Instability", in R. Burke and C. Cooper, *The Organization in Crisis – Downsizing, Restructuring and Privatization*, Massachusetts: Blackwell Publishers Ltd.

Lev, B. and S. Radhakrishnan (2003), *The Measurement of Firm-Specific Organization Capital*, NBER Working Paper No. 9581, National Bureau of Economic Research, Cambridge, MA.

Lev, B. and S. Radhakrishnan (2005), "The valuation of organizational capital", in C. Corrado, J. Haltiwanger and D. Sichel (eds), *Measuring Capital in the New Economy*, National Bureau of Economic Research, Studies in Income and Wealth, Vol. 65, Chicago: University Chicago Press, pp. 73-110.

Lichtenberg, F.R. (1993), *R&D Investment and International Productivity Differences*, NBER Working Paper No. 4161, National Bureau of Economic Research, Cambridge, MA.

Mankiw, N., P. Romer and P. Weil (1992), "A contribution to the empirics of economic growth", *Quarterly Journal of Economics*, Vol. 107, No. 2, pp. 407-437.

Marrano, G.M., J. Haskel and G. Wallis (2007), *What happened to the knowledge economy? ICT, Intangible Investment and Britain's Productivity Record Revisited*, Department of Economics Working Paper No. 603, Queen Mary, University of London.

Nakamura, L. (2010), "Intangible Assets and National Income Accounting: Measuring a Scientific Revolution", forthcoming in *Review of Income and Wealth*.

O'Mahony, M. and M. Vecchi (2003), *Is there an ICT impact on TFP? A heterogeneous dynamic panel approach*, Discussion Papers National Institute.

Park, W.G. (1995), "International R&D Spillovers and OECD Economic Growth", *Economic Inquiry*, Vol. 33, No. 4, pp. 571-591.

Rebelo, S. (1991), "Long-Run Policy Analysis and Long-Run Growth", *Journal of Political Economy*, Vol. 99, pp. 500-521.

Romer, P. (1990), "Endogenous technological change", *Journal of Political Economy*, Vol. 98, pp. 71-102.

Roodman, D. (2009), "How to do xtabond2: An introduction to difference and system GMM in Stata", *Stata Journal*, Vol. 9, No. 1, pp. 86-136.

Sen, A., J.-P. Fitoussi and J. Stiglitz (2009), Report by the Commission on the Measurement of Economic Performance and Social Progress (http://www.stiglitz-sen-fitoussi.fr).

Sichel, D. (2008), "Intangible capital", in S.N. Durlauf and L.E. Blume (eds), *The New Palgrave Dictionary of Economics*, 2nd edition, Basingstoke: Palgrave Macmillan.

Solow, R. (1956), "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, Vol. 70, pp. 65-94.

Solow, R. (1999), "Notes on Social Capital and Economic Performance", in Partha Dasgupta and Ismail Serageldin (eds), *Social Capital: A Multifaceted Perspective*, World Bank, Washington, D.C., pp 6-10.

Subramaniam, M. and M. Youndt (2005), "The influence of intellectual capital on the types of innovative capabilities", *Academy of Management Journal*, Vol. 48, pp. 450-463.

Teece, D. (1998), "Capturing value from knowledge assets: The new economy markets for know-how, and intangible assets", *California Management Review*, Vol. 40, pp. 55-79.

Temple, J. (1999), "The New Growth Evidence", *Journal of Economic Literature*, Vol. 37, No. 1, pp. 112-156.

Van Rooijen-Horsten, M., D. van den Bergen and M. Tanriseven (2008), *Intangible capital in the Netherlands: A benchmark*, Discussion Paper No. 08001, Statistics Netherlands, The Hague.

Webster, E. (2000), "The growth of intangible enterprise investment in Australia", *Information Economics and Policy*, Vol. 12, pp. 1-25.

World Bank (2006), *Where is the Wealth of Nations? Measuring Capital for the 21st Century*, World Bank, Washington, D.C.

Youndt, M., M. Subramaniam and S. Snell (2004), "Intellectual Capital Profiles: An Examination of Investments and Returns", *Journal of Management Studies*, Vol. 41, pp. 335-61.

Appendices

Appendix 1.

Table A.1 Descriptive statistics (1995-2005 EU-15 mean values)

	Obs	Mean	Std. Dev.	Min	Max
GDP[a]	165	543.42	570.90	15.12	1911.11
Total hours worked[c]	165	18216.09	18268.09	370.45	57665.00
Labour productivity in euros (GDP per hour worked)	165	30.17	6.95	14.48	50.59
Log labour productivity	165	3.38	0.25	2.67	3.92
Annual labour productivity growth	150	1.93	1.53	-2.12	7.59
Labour productivity in euros[b]	165	31.90	8.31	14.83	60.82
Log labour productivity[b]	165	3.43	0.27	2.70	4.11
Annual labour productivity growth[b]	150	2.06	1.61	-2.29	7.37
At least upper secondary education in %	165	60.44	16.93	17.80	83.90
Log education	165	4.05	0.35	2.88	4.43
Capital stock[a]	165	1582.69	1693.17	28.35	6023.12
Annual capital stock growth	165	2.59	1.31	0.01	6.20
Intangible capital stock[a]	165	64.48	81.39	2.75	306.48
Annual intangible capital stock growth	150	4.94	3.24	-2.14	19.45
Proxy business cycle (1-unemployment rate)	165	0.92	0.03	0.81	0.98
Government efficiency	105	1.70	0.45	0.60	2.27
Political Stability	105	0.99	0.37	0.27	1.67
Openness	150	95.45	57.84	41.25	286.48
Inflation	150	90.82	6.50	72.68	100.00
FDI stock inward in % of GDP	121	39.57	34.90	7.00	139.00
Social exp in % of GDP	164	25.90	4.64	12.00	34.30
Education exp in % of GDP	165	5.47	1.31	2.50	8.20
Government exp in % of GDP	165	47.59	6.66	31.50	65.10
Income tax in % of GDP	165	13.74	5.21	6.00	28.90
Stock market capitalization in % of GDP	154	76.40	49.34	12.78	283.99

[a]Billions of constant 2000 PPP euros

[b]Labour productivity as above augmented by investment in intangible capital investment

[c]Million hours

Appendix 2. Theoretical reasoning for core and control variables

When studying the link between business intangible capital measures and labour productivity growth, it is necessary to control for additional important determinants of growth. In classical growth theory, growth was originally modelled based on a production function with the inputs of physical capital and labour. Differences in physical capital accumulation or in investment rates across countries can explain to a large extent the differences in economic growth that exist between countries. The factor labour (the amount of workers in the economy) is necessary to work with the machines and to invent new technologies. Since we are studying labour productivity (GDP per hours worked), we include as a control variable the number of hours worked per hour and country rather than the number of workers.

Another determinant of growth that has been fully recognised in economic theory is human capital. At first, human capital was introduced into the production function as a third input factor alongside capital and labour. Later, in the context of the endogenous growth theory,[19] human capital was modelled as a factor determining technological progress. The assumption behind this approach is that a more educated workforce is more likely to create new technologies and is better equipped to handle this new often complex technological know-how. As a measure of human capital, we include the percentage of the population with an upper secondary or higher degree.

In our baseline model, we also include a lagged income term. Controlling for the income level of each country enables us to control for the convergence of poor countries to the levels of rich countries. Solow (1956) showed in his model that countries converge to a steady state growth path with a convergence rate that increases with the distance towards the steady state. In other words, including a lagged income term accounts for the theoretical insight and empirical observation that poor countries tend to grow faster than rich countries.[20]

The last variable we include in our baseline model is a proxy for business cycle fluctuations, which is specified as one minus the rate of unemployment. It is necessary to

[19] See for example Romer (1990).

[20] See also Barro (1991) and Mankiw, Romer and Weil (1992).

include this variable since we are working with annual growth data rather than long-term growth.

In our sensitivity analysis we control for a number of variables indicating the countries' macroeconomic policy setting, their financial development and indicators of international trade. An important element of macroeconomic policy is the management of inflation rates. Lower and more stable inflation rates provide a more certain economic environment, which encourages investors. More investment in turn leads to enhanced capital accumulation and to higher growth. Evidence shows that high inflation rates hamper growth; but for lower levels of inflation, findings on the relationship between inflation and growth are not so clear-cut.[21] In our analysis we include a measure of the inflation rate in levels.

Another element of macroeconomic policy is the government's fiscal policy. Government expenditure and taxation tend to have a positive effect on growth when they are kept at low levels but a negative effect at high levels. This is especially the case when government expenditure is devoted to unproductive activities or when taxes are more distortionary. Fiscal policy could also have a negative impact on growth if it interferes negatively with monetary policy. This could be problematic since monetary policy might become less credible which would lead to risk premia in interest rates and thereby hamper capital accumulation.[22] We include in our sensitivity analysis a measure of income tax as a percentage of GDP, a measure of total government expenditure as a percentage of GDP and measures of social expenditure and educational expenditure likewise as percentages of GDP.

A country's policy setting is also characterised by government efficiency and stability. The former is likely to be important for government expenditure and other fiscal policies to be effective and the latter contributes to providing an enhanced environment for investors. As noted in Section 4.2, these indicators can be used as proxies for trust and social capital.[23] We see social capital as a form of intangible capital. Thus, the indicators can be interpreted as an additional measure of intangible capital in our model. We use

---

[21] See Bassanini and Scarpetta (2001).
[22] Ibid.
[23] See World Bank (2006).

two indicators from the list of the Kaufmann–Kraay–Mastruzzi Worldwide Governance Indicators.[24] The first indicator is "government effectiveness", which measures "the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies". The second indicator we use is "political stability and absence of violence", which measures "perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism".

Beside fiscal policies, the financial development of a country determines growth. The financial structure is especially important for the funding of capital accumulation. If the financial system is efficient, it will guide investment and savings towards promising new technologies. However, Bassanini and Scarpetta (2001) mention a possible negative effect of financial development. They claim that the good investment conditions enabled by a well developed financial system may give households less incentive to save. Bassini and Scarpetta (2001) also mention the problem of reverse causality between financial development and growth since growth might be an element enhancing the development of the financial system. Our econometric methodology will address this issue as described below. In our analysis we use stock market capitalisation as a percent of GDP as an indicator of financial development. Stock market capitalisation is a measure of the value of all stocks in the market. It can be interpreted as a public opinion on the value of businesses. According to Bassanini and Scarpetta (2001), this is an indicator of the possibilities for fund raising on the equity markets.

It is not only an economy's internal market that fosters growth, but also its presence in external markets. Another set of variables that are thought to be relevant in growth analysis are indicators of a country's position in international trade. According to the economic theory of international trade, the benefits of trade are more traditionally the possibility to make use of comparative advantages and – according to more modern theories – the exploitation of economies of scale, the diffusion of knowledge and more competition leading to lower prices, higher quality or more diversification. These benefits

[24] See for example Kaufmann, Kraay and Mastruzzi (2008).

imply more efficiency and could thereby lead to a higher level of investment and growth. As measures of a country’s position in terms of international trade, we use the stocks of inward foreign direct investment (FDI) and an indicator for the openness to trade. It is constructed as the sum of exports and imports in constant prices.

Appendix 3. Detailed description of the construction of the business intangible capital variables

Corrado, Hulten and Sichel (2005) group business intangible capital investments into three groups: i) computerised information, ii) innovative property and iii) economic competencies.

Excluding all elements cited by Corrado, Hulten and Sichel (2005) – the measurement of which already exists in the GDP measure provided by the AMECO dataset (inclusion of mineral exploration, computer software and entertainment and literary or artistic originals[25]) – the INNODRIVE macro approach has measured the following six measures of 'new' business intangible capital investment: i) scientific R&D, ii) product development costs in financial services, iii) advertising expenditure, iv) expenditure on market research, v) firm-specific human capital and vi) organisational capital. The variables are constructed for the business sector and the data are therefore taken for the NACE sectors C to K and O.

To measure scientific R&D, data on Business Expenditure and Research and Development (BERD) were retrieved from Eurostat. Missing data were inter- and extrapolated. To avoid double-counting of software investment, data for "K72 – Computer and related activities" were subtracted from the R&D variable and J was subtracted to avoid double accounting with the investment in the development of new products within the financial services industry. As investment in scientific R&D should be accounted as an investment of 100%, the investment in R&D was fully accounted as investment in intangible capital.

Product development in the financial services industry was measured, again according to Corrado, Hulten and Sichel (2005), on the basis of 20% of total intermediate spending for intermediate inputs by the financial intermediation industry, which is defined as excluding insurance and pension funding (NACE J65).

To construct the investment in advertising variable, a private data source (Zenith Optimedia) was used. Landes and Rosenfield (1994) found that in the US, around 60% of advertising expenditure could be capitalised; therefore, Corrado, Hulten and Sichel

[25] These elements have recently been included in the gross fixed capital formation investments. See the list of variables for the AMECO dataset: http://ec.europa.eu/economy_finance/db_indicators/ameco/documents/list_of_variables.pdf

(2005) recorded 60% of advertising expenditure as investment. Consequently, only 60% of the actual expenditure was considered investment. In order to construct the variable on investment in market research, the data on the turnover (v12110) for “k7413 – Market research” from Eurostat’s Structural Business Survey dataset were taken. The data on the turnover for K7413 were slightly modified by comparing them with data from an additional source – ESOMAR (European Society for Opinion and Marketing Research). In a next step, public sector expenditure was subtracted from the data by considering public sector consumption as a percentage. Afterwards, the shares between K74 and k7413 were applied. A methodology was applied to calculate the share for the business sector c-k + o except 70. Finally, following the approach of Corrado, Hulten and Sichel (2005), the prevalence of own-account market and consumer research was estimated by doubling the estimate of the data on market research.

Data on firm-specific human capital were taken from Eurostat’s Continued Vocational Training Survey (CVTS). This variable is a measure of the training expenditure and it is computed as the cost of continued vocational training courses as a percentage of total labour cost multiplied by employee compensation. Missing data were interpolated and the share was held constant before 1999. The estimation method is applied at the industry level and the measures are then aggregated to obtain data on the national level.

Corrado, Hulten and Sichel define investments in organisational change and development as the sum of two components: the purchased component (represented by management consultant fees) and the own-account component (represented by the value of executive time spent on improving the effectiveness of business organisations, i.e. the time spent on developing business models and corporate cultures).

Data on own organisational capital are taken from the Structural Earnings Survey (SES) and the Labour Force Survey (LFS). Organisational capital is measured by the own-account investment in the organisational structure of a firm. To construct this variable it was assumed that 20% of manager compensation is spent on investment in the organisational structure of a firm. Manager compensation is computed as the manager compensation share multiplied by the compensation of employees. The manager compensation share is the share of gross earnings of managers over the gross earnings of employees. Data on purchased organisational capital are taken from Eurostat and the FEACO Survey of the European Management Consultancy Market. Purchased organisational capital is represented by management consultant fees. In order to compute this measure, the business sector expenditure on organisational structure was estimated as the share of NACE 7414 purchased by the business sector in gross output of the NACE 7414. It was assumed that 80% of this expenditure is considered an investment.

Appendix 4. Categorisation of advertising, market research and scientific R&D as gross fixed capital formation

Advertising

If we apply criteria i to iv to advertising expenditure, we can argue that:

i) expenditure on advertising is identifiable, i.e. is capable of being separated and sold, transferred, licensed, rented or exchanged, either individually or as part of a package, as the results, especially market data research, can easily be sold to other agents;

ii) it is possibly to identify who owns the asset, as firms that spend money on market research own the data and the results, and they have more knowledge of the specific market structures;

iii) the asset produces economic benefits for its owner, as the expenditure on market research contributes to the value of the brand and in this sense produces benefits for the owner; and

iv) it is expected that the asset will provide capital services for over a year in the production of different products.

Market research

If we consider criteria i to iv for market research expenditure, we can argue that:

i) expenditure on market research is identifiable, e.g. is capable of being separated and sold, transferred, licensed, rented or exchanged, either individually or as part of a package, as the results, especially market data research, can easily be sold to other agents;

ii) it is possible to identify who owns the asset, as firms that spend money on market research own the data and the results, and they have more knowledge of the specific market structures;

iii) the asset produces economic benefits for its owner, as the expenditure on market research contributes to the value of the brand and in this sense produces benefits for the owner; and

iv) it is expected that the asset will provide capital services for over a year in the production of different products.

Scientific R&D

If we apply criteria i to iv for scientific R&D expenditure, we can argue that:

i) Expenditure on R&D is identifiable, e.g. is capable of being separated and sold, transferred, licensed, rented or exchanged, either individually or as part of a package, as spending money on R&D activity usually leads to a patent or a license.

ii) It is possible to identify who owns the asset, as normally it is the cooperation or institution that performs the research and spends the money that is the owner of the asset. This could be a company, a government, a higher education institute or a private non-profit company.

iii) The asset produces economic benefits for its owner, as the money that is spent on R&D has the clear purpose of creating new products, patents or licenses and optimising the existing production processes to exploit them in the future by selling those licenses and increasing the production capacity by means of the innovative production processes.

iv) It is expected that the asset will provide capital services for over a year in the production of different products, as most often the profits from licenses and patents yield benefits.