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Intangible capital and economic growth: empirical evidence from Luxembourg

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Acknowledgement

I would like particularly to thank the Institut national de la Statistique et des Etudes Economiques (STATEC) staff and above the Director Serge Allegrezza, Vice Director Nico Weydert and Denise Schroeder Head of General Services Division, for having given me the opportunity to conduct the present research in this friendly environment workplace institution. I really enjoyed my stay here. I am indebted to my supervisor Dr. Michel Prombo researcher at STATEC who provided me with useful advice and suggestions that have immensely contributed to improving this paper. I also owe many thanks to Pr. Dr. Alexandru Minea, from the school of economics of the University of Auvergne, Dr. Wladimir Raymond and Dr. Anne Dubrocard researchers at STATEC for their thoughtful and helpful comments. Last but not the least I am grateful to my parents, friends, student colleagues and other individuals who have contributed directly or indirectly to the present paper with supports, advice and pray. Thank you everyone. May the almighty bless you all so much.

Needless to say that all the remaining weaknesses and errors are my own responsibility.

INTANGIBLE CAPITAL AND ECONOMIC GROWTH: EMPIRICAL EVIDENCE FROM LUXEMBOURG

Nikiema Kader Charlemagne

May 13, 2015

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This paper is the first effort to analyze the role of intangible capital in contributing to GDP and labor productivity growth in Luxembourg from 1996 to 2012 using the definition and evaluation framework of intangibles from Corrado et al. (2005, 2012), which includes a broader range of assets than the classical national accounting system. The annual average investment in intangible assets is about 2.4 billion euros in Luxembourg from 1995-2012 which represents 8.67 % of GDP and capital stock is estimated to 10.1 billion euros in 2012. Compared to its neighbors (Belgium, France, Germany) and The Netherlands, Luxembourg invests more in intangible assets relatively to GDP. However the growth rate of intangible capital stock has been falling in Luxembourg while the trend of the accumulation in the neighboring countries is upwards. The growth accounting analysis suggests that the full capitalization of intangibles tends to increase GDP and labor productivity growth when the accumulation of intangible assets is speeding up, while a slowdown tends to affect adversely the growth rate of GDP and labor productivity in Luxembourg. But the growth impact of intangible capital is rather low in comparison to neighboring countries and The Netherlands.

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1 INTRODUCTION

The factors influencing economic growth and fundamentally economic development continue to be the subject of extensive debate. The economic literature has investigated the drivers of economic growth for decades and has emphasized the role played by investments in physical capital (tangibles) and labor. However, for an economy near the technology frontier, it is not enough to simply have ample labor force and machinery. Human capital and innovation are fundamental engines of economic success. More recently, it is knowledge creation and the role of intangible capital that are being increasingly recognized as key factors of productivity and economic growth both at the micro and macro levels of analysis. According to Corrado, Hulten and Sichel (2005, 2006) (CHS hereafter), investments in intangibles refer to all those capital forms that are theoretically important to boost output and expand future productive capacity but are not tangible in nature. Examples include outlays for computer software, public and private research and development, training, brand equity, and improvements in organizational structure and efficiency. "These are strategic investments in the long-run growth path of individual companies and of the economy as a whole" (van Ark et al., 2009). They are essential for a sustained economic health of the economy (European-Commission, 2010) and vital for the future competitiveness of highly developed economies as they transform more and more into knowledge economies (CHS, 2005). According to the World-Bank (2006), intangible capital accounts for 78% of the world wealth.

Despite the apparent long-lasting benefits of intangibles, fully identifying and measuring them are challenging. Another important issue is that the system of national accounts is still treating most spending on intangible assets as intermediate consumption rather than investment.

The seminal papers of CHS (2005, 2006) addressed these issues and found that capitalizing intangibles in US national statistics increases the estimates growth rate of output per hour by 10-20 %. Their works have paved the way for several recent empirical country-case studies for Canada (Baldwin et al., 2012), France (Delbecque et al., 2012), The Netherlands (Van Rooijen-Horsten et al., 2008), UK (Marrano et al., 2009), Japan (Fukao et al., 2009), Sweden (Edquist, 2011), Australia Barnes (2010), Finland (Jalava et al., 2007) etc.

Other studies have tried to replicate the intangible capital measures framework proposed by CHS (2005, 2006) for the US for a set of countries in a comparative analysis: Germany, France, Italy and Spain by Hao et al. (2009); Europe by van Ark et al. (2009); Piekkola (2011); advanced economies by Corrado et al. (2012). These studies focused on quantifying the magnitude of intangible capital investments in the business sector or economy wide level and then assessed how these investments affect some key macro variables such as GDP or productivity growth. Despite showing the overall importance of investment in intangible assets for economic growth in many countries around the world[1], these studies have also revealed a large heterogeneity across countries regarding the level and impact of the accumulation of intangibles. Apart from the UK, many European countries are lagging behind the US figures. Intangible investment exceeds the mark of 10 % of GDP in the US and the UK but is below that threshold in France, Germany and even less in some EU countries such as Italy or Spain. In the US and UK, spending on intangibles is even higher than tangibles and as the results the impact on GDP and labor

[1] According to van Ark et al. (2009), intangible capital explains about a quarter of labor productivity growth in the US and larger countries of the EU

productivity growth is much larger.

To the best of my knowledge, no study has investigated the role of intangible capital in Luxembourg economy. Thus the purpose of this study is to examine whether intangibles represent an important economic driving force in Luxembourg. More specifically, the project seeks to find answers to the following questions:

1. How large are investments in intangible assets in Luxembourg?
2. How does it compare to investments in tangibles?
3. How does investment in intangibles in Luxembourg compare to other advanced economies especially neighboring countries?
4. What is the contribution of intangible capital to productivity and economic growth in Luxembourg? Does treating expenditure on intangibles as capital rather than just intermediate inputs make considerable difference to measured GDP and labor productivity growth in Luxembourg? If so, to what extent would their capitalization in official statistics impact published growth rates compared to the hypothetical case where they are excluded from national accounts?
5. What is the relative importance of investment in intangibles for economic growth in Luxembourg in comparison to other high wage economies?

The main literature on the contribution of intangible capital to economic growth makes use of the growth accounting analysis which consists in assessing the economic growth between the contributions of its factor inputs (Solow, 1956). The unavailability of sufficient long time series data on intangible capital has constrained researchers to rely on the accounting methodology. However recent progress in the measurement of intangibles has gradually increased the number of countries for which data on intangibles are available not just at macro or market sector level but also at a more disaggregated level of industry or sectoral level. This has allowed first attempts to assess the impact of intangibles from a panel econometrics analysis at macro level (Roth and Thum, 2013), (Corrado et al., 2014)[2] and explore their role in a much deeper analysis of industries and economic sectors: for The UK (Goodridge, 2012), for Japan and Korea (Chun et al., 2012), for France (Delbecque and Bounfour, 2012), for Germany (Crass et al., 2014) and for a set of 10 European countries(Niebel et al., 2013).

Due to data limitation, the present study follows the accounting approach to assess the contribution of intangible capital in Luxembourg. It assumes investments in intangibles to play an important role in sustaining long-run economic growth in Luxembourg.

The outline of the rest of the paper is as follows.

Section 2 documents the measurement methods and data sources used to estimate the magnitude of intangible capital investments in Luxembourg. Section 3 provides a descriptive analysis about the level and major trends of intangible investments in Luxembourg with a cross country-comparison including the neighboring countries (Belgium, France and Germany), The Netherlands and US. Section 4 constructs and reports estimates of the stock of intangible capital in Luxembourg. Section 5 describes the extended growth

[2]these papers have relied upon internationally comparable data on intangibles at the country and sectoral levels constructed based on the approach by CHS, (2005) within the projects INNODRIVE (Jona-Lasinio et al., 2011) and COINVEST (Corrado et al., 2012) funded by the European Commission and The Conference Board.

accounting framework applied to examine the impact of intangible capital on output and productivity growth and presents the empirical results. The final section summarizes the study results and their policy implications, and discusses future tasks.

2 MEASURING INTANGIBLE INVESTMENTS

2.1 Measurements Issues and Methods

Intangible capital defines itself exactly as not being tangible i.e solid, often durable things such as buildings or machinery that can be expected to yield productive services for some time. Until very recent time, the literature on intangible investment has focused only on R&D capital, leaving outside important other elements such as brand equity or improvements in organizational structure and efficiency. Given the nature of intangible, estimating its amount and quality in order to document its effects on productivity for instance, is a challenging task. The measurement challenges have been acknowledged by the former US Fed Chairman Ben Bernanke in 2011: "We will be more likely to promote innovative activity if we are able to measure it more effectively and document its role in economic growth" and the US BEA Director Steve Landefeld in 2006: "No one disagrees with the capitalization of intangibles such as R&D conceptually. The problem is in the empirical measurement." Although these comments may have called into question the possibility of measuring intangible capital, they seem to have been too pessimistic.

Three main approaches to measuring intangibles can be identified in the economic literature: financial valuation, performance measures and direct expenditure assessment.

According to the financial market valuation approach, the value of intangible capital is determined by the difference between the market value of firms and the value of tangible assets. References to the application of this method are Brynjolfsson and Yang (1999) and Brynjolfsson et al. (2000).

The second method relies on performance measures such as productivity or earnings to infer the magnitude of intangible capital. For examples,Cummins (2005); McGrattan and Prescott (2005); Lev and Radhakrishnan (2005) used this methodology in order to estimate the value of intangibles at the level of individual firms.

The third approach uses direct expenditure data to develop measures of investment in intangible assets. Nakamura (1999, 2001) was the first to adopt expenditure-based measures of intangibles including R&D expenditure, software, advertising and marketing expenditure and wages and salaries of managers and creative professionals.

There is a long history of attempts to measure intangible investment but until recently with the work of CHS, no significant step in the measurement of intangible capital was made at macro level. CHS argued that an input should be treated as an investment as long as it reduces current consumption with the aim to generate revenues in the long term. Expanding on Nakamura's work they provide a broad list of intangible assets to be measured, grouped into three categories: computerized information, innovative property and economic competencies. Computerized information consists of investments in computer software and databases. Innovative property is captured by the following five components: mineral exploration, scientific R&D, copyright and licenses, new product development costs in the financial industry and spending on new architectural and engineering designs. Economic competencies include investments aimed at raising productivity and profitability as brand equity (advertising and market research) and firms specific human capital (employer provided training and organizational structure). Using

CHS framework I document the data sources used to estimate intangible investments in Luxembourg.

2.2 Data Sources and Description of the Construction of Business Intangible Capital Variables

The data sources are provided for the measurement of each single item listed in the categorization of intangibles by CHS for the business sector or market sector level (NACE[3] sectors C to K and O) of analysis from 1995 to 2012.

2.2.1 *Computerized information*

The first category, computerized information, reflects knowledge embedded in computer programs and computerized databases. It is made up of investments in purchased and own account computer software and the investments in new computerized databases.

- ***Investment in own account computer software***

Information on computer software expenditure in Luxembourg can be found in national accounts official statistics namely in the Gross Fixed Capital Formation (GFCF) table. GFCF table provides an annual data on software expenditures for the economy wide level which includes non-financial corporations, financial corporations, public sector and households, non-profit institutions serving households. As the present study is interested in evaluating investments in intangible capital in Luxembourg in the business sector, annual computer software expenditures from 1995 to 2012 are derived for the business sector by excluding the economic activities of general government, private households and nonprofit organizations serving individuals from the total economy or just summing up expenses of non-financial corporations and financial corporations which constitute the business sector in the GFCF table.

- ***Investment in new computerized databases***

Spending on computerized databases is not recorded in national accounts. In accordance with the assumption by Piekkola (2011), who considers software and databases indistinguishable, the present study supposes expenses on computerized databases to be captured by software figures.

2.2.2 *Innovative property*

- ***Scientific R&D***

Although there has been recently a move to capitalize R&D in national accounting practice by the United Nations in its System of National Accounts (SNA), expenditures on R&D are still considered as intermediate consumption rather than capital formation in Luxembourg aggregate accounts, in spite of their inherent investment nature which aims at future benefits. The data on scientific R&D are constructed using data on Business Expenditure on Research and Development (BERD) from Eurostat which provides

[3]NACE stands for Nomenclature générale des Activités économiques dans les Communautés Européennes. It refers to the industrial classification used by Eurostat

reliable and convenient information over the time frame of analysis of the present study on sector K72 and sector J allowing their exclusion from the overall BERD to avoid double counting. Scientific R&D expenditure is fully accounted (100%) as investment in intangible capital.

- ***Mineral Exploration and Copyright and license costs***

The main data source is STATEC GFCF table. Mineral exploration and Entertainment, literary and artistic originals subject to copyrights and licenses constitute with computer software, the intangible assets recorded in national statistics. Assuming as in Corrado et al. (2012), all GFCF in mineral exploration and new motion picture films and other forms of entertainment are performed by firms included in the business sector.

- ***New product development costs in the financial industry***

Considering that the development of new financial products produces know-how that meets the criteria of an asset as it is identifiable and produces economic benefits for more than a year to the financial institution that has developed it, Corrado et al. (2012) assume that 8% of compensation of high skilled in industry J is a good approximation for the innovation expenditure in financial industry. The same approach is applied to estimate new financial product development expenditure of Luxembourg using the World Input-Output Database (WIOD).

- ***New architectural and engineering designs***

In accordance with the methodology by CHS who assumes 50% of the total turnover of sector "7420-Architectural and engineering activities and related technical consultancy" (NACE rev1) to estimate business investment in new architectural and engineering designs, STATEC Structural Business Statistics (SBS) is used to construct Luxembourg investments in this asset type. SBS is a favorable dataset as it includes information on turnover, production value and value added at factors costs by sectors according to NACE rev1 classification.

2.2.3 *Economic competencies*

- ***Advertising expenditure***

Expenditure on advertising aims at creating a perceived image of the firm namely reliability and trustworthiness which drives the choice of the consumer. Advertising expenditure contributes to the value of the company brand and is likely to produce in this sense economic benefits. Therefore, advertising expenditure should be considered as an investment which yields future benefits. The data on advertising expenditure is extracted from STATEC SBS which provides information on turnover for sector K744 Advertising (Rev 1.). Only 60% of the actual expenditure is considered investment in accordance with CHS.

- ***Market research***

Just as advertising expenditure, CHS consider expenditure on market research to contribute to the value of company brand name. Knowledge of market segments and consumer attitudes might generate benefits accruing to the firm beyond a time period of one year. Therefore the national accounting system should regard expenditure on market research as an asset and business investment rather than intermediate cost.

The variable on investment in market research is constructed taking the data on the turnover (v12110) for "k7413 - Market research" from Eurostat's Strutural Business Survey for the period of analysis. Using STATEC structural data does not allow the distinct identification of sector k7413 as it includes information on turnover of sector "Market research and public opinion polling, business and management consultancy activities and management activities of holding companies" (K74.13/74.14/74.15).

- ***Firm specific human capital***

Several databases are available for the computation of firm specific human capital: Continuing Vocational Training Survey (CVTS) from Eurostat, Labor Cost Survey (LCS) from Eurostat, national accounts from STATEC and Socio-Economic Accounts from World Input-Output Database (WIOD). Using compensation of employees retrieved from the national accounts STATEC for its accuracy and time/sectors coverage, investment in firm-specific human capital, made up of expenditure in vocational training and apprenticeships, is obtained following the steps of CHS. It is computed as the cost of continued vocational training courses as a percentage of total labor cost multiplied by employee compensation. Missing data were interpolated.

- ***Organizational structure***

The economic literature considers organizational capital among the most important factors driving corporate performance and growth. It is 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" (Lev and Radhakrishnan, 2005).

CHS define investments in organizational 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 organizations, i.e., the time spent on developing business models and corporate cultures).

Using STATEC internal Structure of Earnings Survey (SES) and Labor Force Survey (LFS)from Eurostat, estimate of own account development of organizational structure is derived by replicating the methodology of CHS. It is assumed that 20% of manager compensation is spent on investment the organizational 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 organizational capital are taken from Eurostat and the FEACO Survey of the European Management Consultancy Market. Purchased organizational capital is represented by management consultant fees and is computed as the share of NACE 7414 purchased by the business sector in gross output of the NACE 7414. 80% of this expenditure is assumed to be an investment.

3 INTENSITY OF INTANGIBLE INVESTMENTS: DESCRIPTIVE ANALYSIS AND CROSS-COUNTRY COMPARISON

This section analyzes the level and dynamics of intangible investments in Luxembourg and compare it with some selected countries namely its neighbors (Belgium, France and Germany) plus Netherlands and the US.

3.1 Stylized Facts

3.1.1 *The level of intangible investments*

Table 1 gives some idea of the scale of expenditures in intangibles in Luxembourg. It reports the annual average amount of intangible investment by category and the corresponding GDP share for the overall business sector in Luxembourg by five years span starting in 1995. The annual average investment in intangibles stood at 2,433 million euros (current prices) from 1995-2012 which represent 8.67 % of GDP. Investment in intangibles has risen over time from 1995-2012. The annual average amount of money invested in intangibles rose from 1,603 million euros in the second half of the 90s to 2,473 million euros the first half of 00s and stood in the last half of 00s up to 3,050 million euros. Expenditure in intangibles has increased by a factor of 2.64 between 1995-2012 which correspond to an annual growth rate of roughly 5.5 % to top up 3,377 million euros in 2012. Despite the rise of money invested in intangibles since 1995, its portion in GDP has declined during the overall period (0.4 % on an annual basis) due to a faster growth of GDP (multiplied by a factor of 2.84 which correspond roughly to 6 % annual average growth). Figure 1 in the appendix shows the evolution of the share of intangible investments in GDP and clearly depicts the decreasing trend of the share.

Table 1: Intangible Investment by Category - Millions of Euro and percentage of GDP (Current Prices and Average for period shown)

	1995-2000		2001-2005		2006-2010		1995-2012	
	€	GDP Share	€	GDP Share	€	GDP Share	€	GDP Share
Computerized Information	**150**	**0.85**	**358**	**1.28**	**289**	**1.03**	**245**	**0.87**
Software	150	0.85	358	1.28	289	1.03	245	0.87
Innovative Property	**544**	**3.06**	**736**	**2.62**	**1 000**	**3.56**	**784**	**2.79**
R&D	355	2.00	392	1.40	467	1.66	404	1.44
Architectural Design	120	0.67	240	0.86	357	1.27	246	0.88
Mineral Exploration & Arts	27	0.15	22	0.08	25	0.09	35	0.13
New Financial Product	43	0.24	81	0.29	151	0.54	99	0.35
Economic Competencies	**908**	**5.11**	**1 379**	**4.91**	**1 761**	**6.28**	**1 404**	**5.00**
Advertising	66	0.37	105	0.37	137	0.49	106	0.38
Market Research	88	0.50	104	0.37	58	0.21	86	0.31
Training	169	0.95	258	0.92	358	1.28	274	0.98
Organizational Capital	584	3.29	912	3.25	1 208	4.31	937	3.34
Total Intangible	**1 603**	**9.02**	**2 473**	**8.82**	**3 050**	**10.87**	**2 433**	**8.67**

Notes: All figures for investments in intangibles are constructed using the evaluation framework of CHS, 2005.
Source: Author's calculation

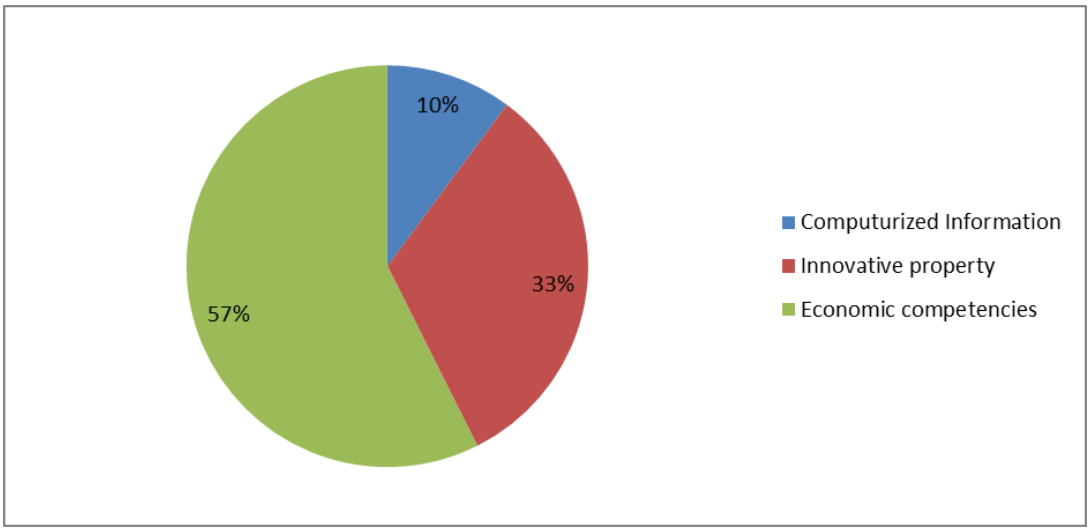
Looking at a more disaggregated level of analysis, I first examined the shares of each group and subgroup of intangible investment compared to the total investment in

intangibles in Luxembourg and then analyzed each group's and subgroup's evolution over time.

Figures 1 and 2 respectively show the average composition of CHS intangibles by group and sub-group as a percentage of total investment in intangibles between 1995 and 2012. The largest component of intangible investment in Luxembourg is economic competencies with a share of nearly 57 % between 1995 and 2012. Organizational capital is the biggest sub-group of economic competencies (two third) followed by employees trainings (20 % approximately)[4] . Innovative property represents the second largest component on intangible investment in Luxembourg. About 33 % is on innovative property of which scientific R&D and new architectural and engineering designs are the main component (around 55 % and 30 % respectively)[5] . Computerized information is the smallest part of intangible investment (10 %) and is made up entirely by software expenditures[6].

As figure 2 shows, organizational capital represents the biggest intangible asset investment in total investments in intangibles. It accounted on average to 38 % of intangible investments between 1995-2012. Expenditures on Scientific R&D, employee training, new architectural and engineering designs and software are the other major intangible assets invested in Luxembourg[7].

Figure 1: Composition of Intangible Investment by CHS Components 1995-2012 (% of total intangible investment)



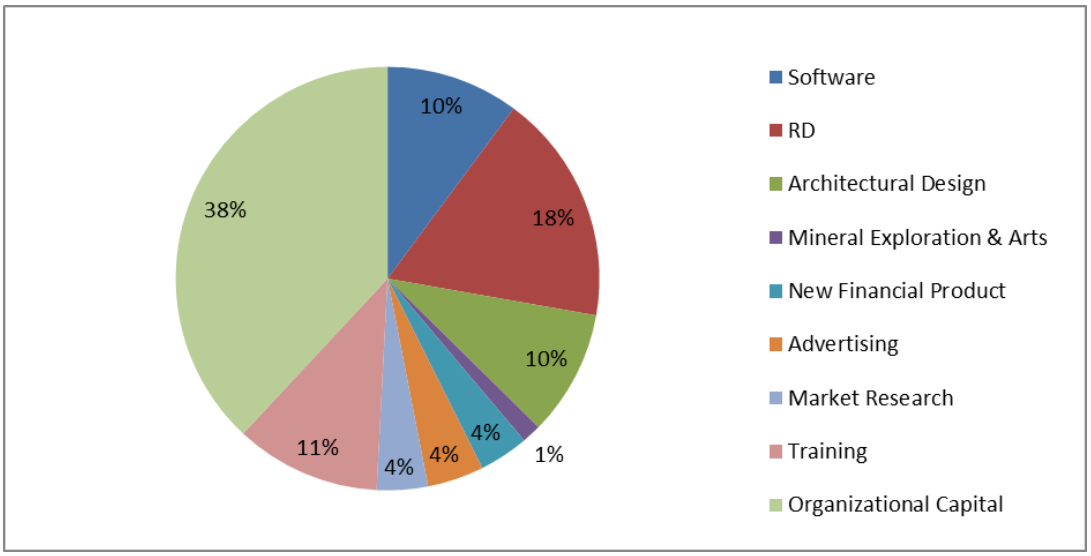
[4]Organizational capital and expenses in employee trainings account for the greatest part of economic competencies (85 %).

[5]Similarly 85 % of innovative property is made up of scientific R&D and new architectural and engineering designs.

[6]Expenditures in computerized database which is the second sub-component of computerized information are assumed to be captured by software figures

[7]Organizational capital, scientific R&D, employee training, new architectural and engineering designs and software constitute 87 % of total investments in intangibles.

Figure 2: Composition of Intangible Investment by CHS Sub-components 1995-2012 (% of total intangible investment)



Coming to the trend in the total intangible investments across each series of CHS intangible asset, I draw figures 3 and 4 to illustrate. Figure 3 breaks the growth in intangible investment into its major components while figure 4 displays in a detailed manner the evolution and contribution of each sub-component from 1995 to 2012. Figures 3 and 4 also show respectively the relative importance of each group and sub group over time. As can be seen, the most dynamic categories of intangibles are economic competencies.

Economic competencies have increased by 2.83 times its value of 1995 at the year 2012. The major drivers of the increase in economic competencies are increase over time of expenditure in organizational capital and employee training which is clearly shown in figure 4. This is not surprising at all given that 85 % of investments in economic competencies are made up of these two assets. Consequently, investments in organizational capital and employee training have accounted for virtually all of the increase of total intangible investments over the last eighteen years[8]. The share in the rise of total investment in intangibles that can be attributed to innovative property has been smaller over time in comparison to the contribution of economic competencies. This smaller contribution is mainly due to the flat evolution of the importance of scientific R&D investments in the increase of innovative property (see figure 4)[9]. Finally the relative importance of computerized information (which is made up of computer software) in the total increase of intangible investments has been the smallest and decreasing since the 2008 financial crisis.

[8]Organizational capital and employee provided training expenditures account to almost half of the total investment in intangibles.

[9]Recall that scientific R&D is the major subcomponent of innovative property investments (55 %).

Figure 3: Evolution of intangible investments - CHS categories (Millions €)

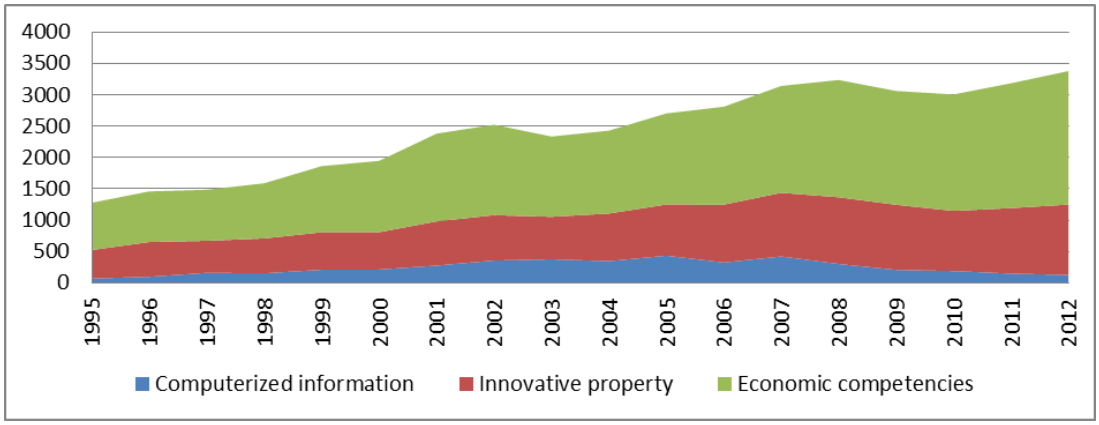
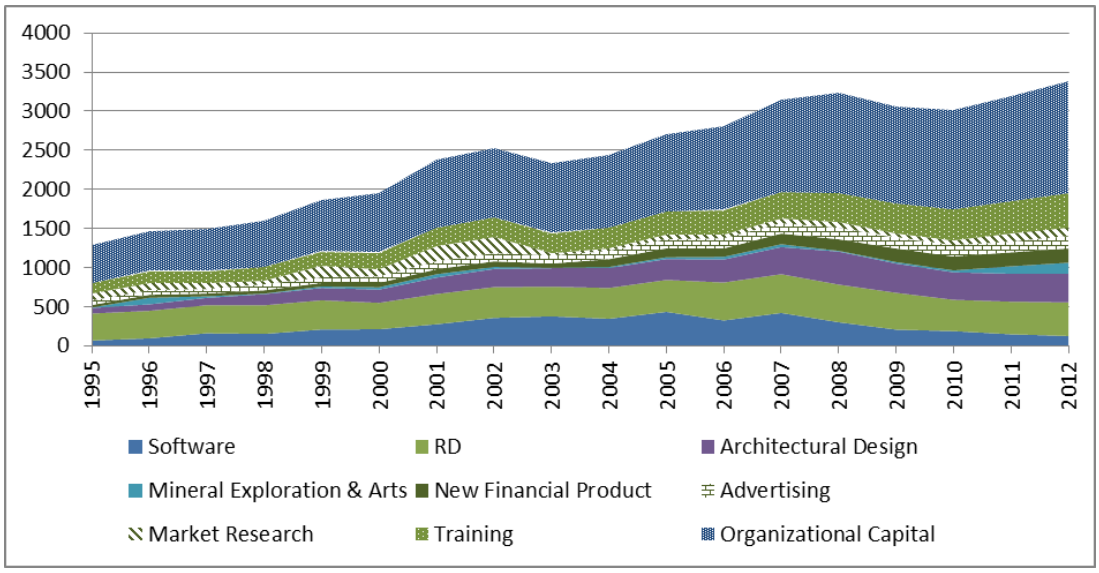


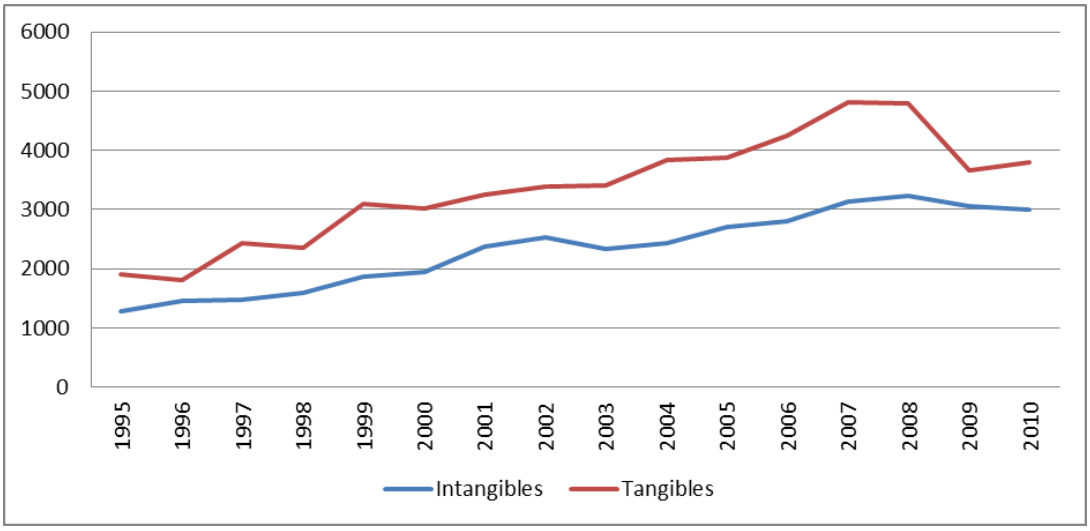
Figure 4: Evolution of intangible investments by assets (Millions €)



3.1.2 *Tangibles and intangibles: comparisons*

Figure 5 shows that the amount of money invested in intangibles has been smaller than tangibles over time since 1995. Investment in intangibles has represented 69 % of tangibles investment on average between 1995 and 2012.

Figure 5: Tangibles VS Intangibles Investments in Luxembourg (Millions €)



But the ratio of intangible to tangible expenditures has been slightly decreasing until the recent financial crisis due to a faster growth of tangibles investments during this period. Expenses on tangibles grew at an annual pace of 7.33 % between 1995 and 2007 while intangibles grew at a smaller rate of 7.16 %. But the collapse of tangible investment in 2008 changed the pattern of the evolution of intangible to tangible ratio in the overall period of 1995-2012. The ratio has been having an increasing trend between 1995 and 2012 instead of decreasing between 1995 and 2007. Tab 1 in appendix gives the trend of intangible-tangible ratio and the annual rate of growth of investment in intangibles and tangibles across different time periods.

3.1.3 *Intangibles capitalized in the national accounts and new CHS intangibles*

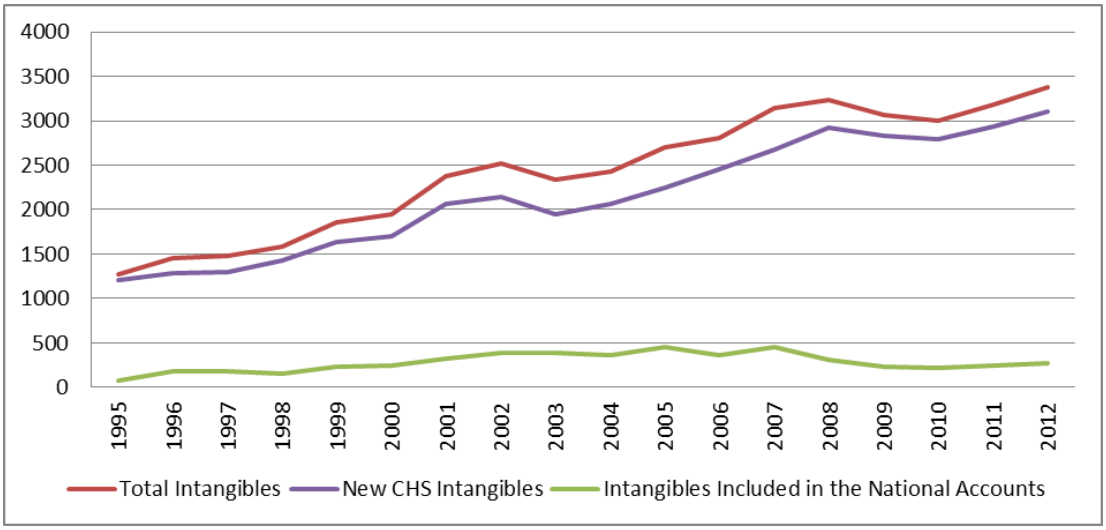
As many other advanced economies, the standard National Accounts treatment of most spending on intangible assets in Luxembourg is as intermediate consumption. Thus they do not count as either GDP or investment. In constructing GDP therefore, spending on R&D for example is treated as spending on electricity, i.e. it is assumed not to be investment and so produces no asset at the end of the period (Marrano et al., 2009). The national accounting practice recognizes only computer software and such non-scientific innovative property as entertainment, artistic and literary originals plus mineral explorations as investments. Luxembourg National Accounts is compiled based on the European System of Accounts (ESA 95) which is fully consistent with the United Nations System of National Accounts (1993 SNA). [10]The focus of this paper relates to what the impact would be on output and productivity growth estimates, of extending a wider range of intangible capital assets as defined by CHS in national statistics (ESA 95) than those already included. Tab 2 in appendix replicates CHS list of intangibles with and without those included in Luxembourg National Accounts according to ESA 95.

[10]The ESA 95 was most recently updated in 2010 (ESA 2010) and is still undergoing a revision to meet the requirements of the update of the SNA 1993 launched in 2003 by the United Nations.

The major category of intangibles, economic competencies which accounts for the biggest part of total intangibles investments, are not capitalized in the National Accounts and so is R&D expenditure which also counts for a significant share in investments of total intangibles. And although there has been recently a move to update the System of National Accounts by capitalizing R&D for instance (seeHulten (2008); Van Rooijen-Horsten et al. (2008)), a full capitalization of CHS listed intangibles in the SNA is for the time being a long road ahead.

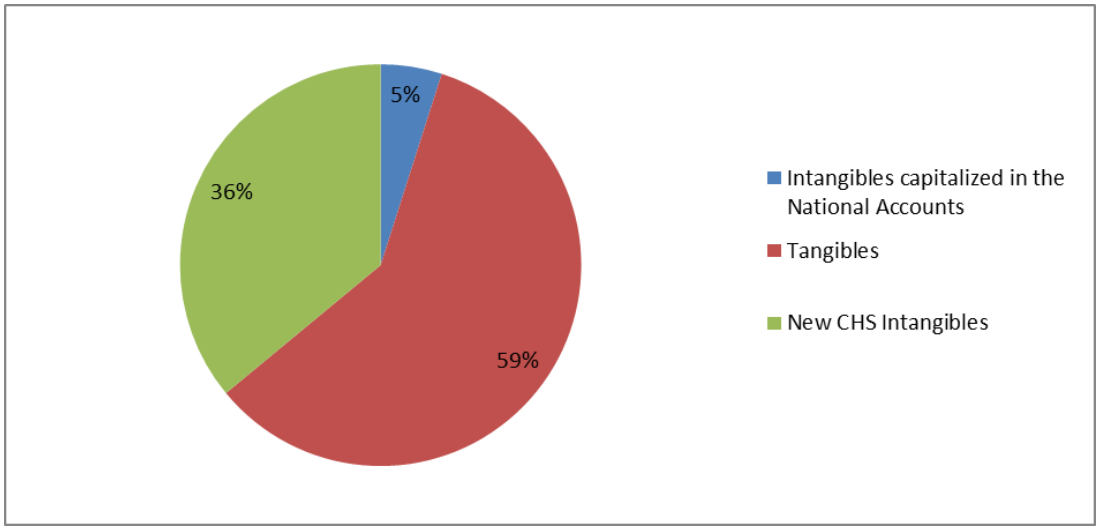
Figure 6 displays the trend of intangible investments capitalized in the Luxembourg National Accounts and New CHS intangibles investments i.e. those that are not capitalized. Unsurprisingly, Intangibles included in the National Accounts represent a small portion of total intangible investments. Total intangible investments is almost made up of New CHS intangibles and his growing trend reflects therefore new CHS intangibles growth pattern. In contrast, investments in intangibles accounted in National Accounts have been flat over time.

Figure 6: National Accounts vs CHS intangibles (Millions €)



The extent to which existing nominal variable measures such as Gross Fixe Capital Formation (GFCF) are understated owing to the treatment of most intangibles as intermediates in the national accounts is illustrated by figure 7. Excluding new CHS intangibles, nominal GFCF totaled an average amount of 3,637 million euros over the period 1995-2010 which represent roughly 14 % of GDP. When new CHS intangibles are accounted for, this raises the total nominal GFCF to 5,630 million euros which is equivalent to approximately 22 % of GDP. Therefore, not capitalizing new CHS intangibles seems to understate nominal GFCF for about 36 %. Whether new CHS intangibles are capitalized or not in national accounting practice does not change the evolution of GFCF GDP share over time. Nominal GFCF-GDP share has been having a downward trend regardless of the accounting practice (see graph 2 in the appendix).

Figure 7: Tangible and Intangible total GFCF Shares 1995-2010



3.2 Cross-Country Comparison

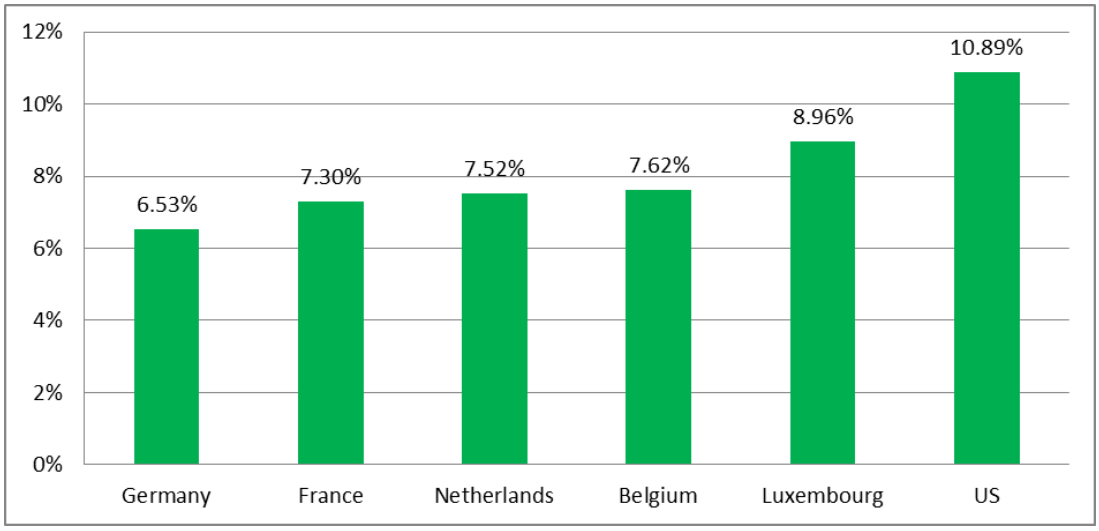
Having detailed above the structure of intangible investments in Luxembourg, I now turn my attention in this sub-section to find out how Luxembourg performs with respect to intangible capital investments in comparison to its neighbors namely Belgium, France and Germany. I also add in the sample comparison, Netherlands and US[11].

3.2.1 *Intangible investment GDP shares*

I begin the comparison looking at the nominal level of intangible capital investment by market sector as a percentage of GDP over the period 1995-2010. As is clearly shown in figure 8 below, Luxembourg outperforms the other European countries with a share of its investment in business intangible capital being nearly 9 % on average between 1995 and 2010. Luxembourg is followed by Belgium and Netherlands whose intangible investment rate is roughly the same (7.62 and 7.52 % respectively) in my sample analysis. The two largest European economies- France and Germany are positioned at the bottom of the distribution (7.30 and 6.53 % respectively). Although Luxembourg exhibits the largest level of business intangible capital investment GDP ratio in the sample of study, its figure is still significantly lower than the US whose intangible investment rate in relation to GDP is the highest than any other country in the world. And as previously said in the introduction, the EU 15 shows a lower propensity to invest in intangibles than does the United States (CHS 2012). But the rates of the US, however, are essentially the same as those for the UK, whose propensity to invest is the biggest in Europe.

[11]The data used here for the purpose of comparison are harmonized business sector and downloadable at http://www.INTAN-Invest.net except for intangible investments in Luxembourg which has been constructed as described earlier.

Figure 8: Intangible GDP shares: 1995-2010 (average values)



3.2.2 *Composition of intangible investments*

Investigating further the pattern of intangible investments across the sample on study, I generate table 2 and the corresponding figure (graph 3 in appendix) to examine the composition of nominal investments in intangibles.

Business intangible capital investments may differ considerably in the sample analysis and to a wider extent across EU countries and the US but the structure of business intangible investments seems to not vary too much. Overall the largest shares of intangibles are in either economic competencies or innovative properties, and only a small part of investment is inside the investment in computerized information (software). Belgium followed by Luxembourg and Netherlands invests the most in economic competencies (around 60 % of total intangible investments are devoted to economic competencies on average between 1995 and 2010). Around half of the amount of money invested in intangibles in US, France and Germany accrued to economic competencies between 1995 and 2010. Germany ranks first with respect to the portion of innovative properties spending in total intangible spending. 41 % of intangibles investments is accounted to innovative properties, an almost equal share in economic competencies (48 %). Then US, France, Luxembourg, Belgium and Netherlands follow with respectively 36 %, 34 %, 32 % and 28 % of innovative property investments. France scores the highest on computerized information total intangible investment share (18 %) followed by Netherlands (15 %), US (14 %), Belgium (12 %) and then Germany and Luxembourg with an equal share of 11 %.

Table 2: Composition of intangible investment (% of total intangible investment)

	Belgium			France			Germany			Luxembourg			Netherlands			US		
Year	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
1995	10	32	58	13	36	51	9	41	49	5	35	59	10	31	59	10	37	52
1996	10	32	59	15	36	50	10	41	49	7	38	55	10	31	59	11	37	52
1997	10	31	59	17	35	48	10	41	48	11	34	55	12	31	57	12	37	51
1998	10	29	60	18	32	50	11	41	48	10	35	55	15	29	56	13	35	52
1999	12	29	59	19	32	49	11	41	48	11	32	57	15	29	56	15	34	51
2000	12	31	57	19	33	48	11	40	49	11	31	58	16	28	57	16	34	50
2001	12	32	56	20	33	47	11	41	48	12	30	59	15	28	57	16	35	49
2002	12	31	57	19	34	47	11	41	48	14	29	57	15	27	58	15	34	51
2003	13	30	57	18	35	47	11	41	48	16	29	55	15	28	58	15	34	52
2004	13	30	57	18	35	47	11	41	47	14	31	54	15	28	56	15	34	51
2005	12	28	60	19	34	48	11	41	47	16	30	54	16	28	55	15	36	50
2006	12	28	59	18	32	50	11	41	47	12	33	56	16	29	54	14	37	49
2007	12	29	59	18	33	49	11	41	47	13	32	54	17	26	57	14	39	47
2008	12	29	59	19	33	48	12	42	46	9	33	58	17	26	56	14	41	45
2009	12	28	60	19	34	47	11	43	46	7	34	59	16	24	60	16	38	46
2010	12	28	60	19	34	47	12	43	45	6	32	62	16	26	58	15	37	48
Average	**12**	**30**	**58**	**18**	**34**	**48**	**11**	**41**	**48**	**11**	**32**	**57**	**15**	**28**	**57**	**14**	**36**	**50**

Notes: 1 = Computerized Information; 2 = Innovative Property; 3 = Economic Competencies. Data on intangible investments in Luxembourg are constructed following the methods described in CHS. 2005, 2006, 2012 Figures for other countries are from INTAN Invest databases.

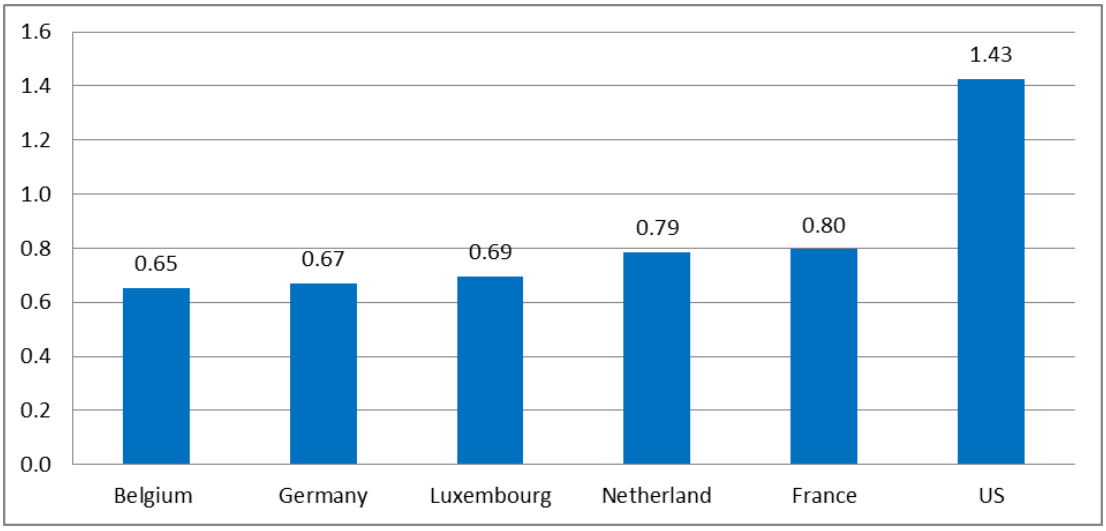
Source: Author's calculation

3.2.3 *Intangible and tangible investment*

Comparing the relative levels of intangible and tangible[12] investments in my sample countries on study, another significant difference emerges (see graph 4 in appendix). The US which has been shown above to have the greatest investment in intangibles relatively to GDP between 1995 and 2010 now ranks at the queue of the distribution regarding its efforts in tangibles investments. In sharp contrast none of the EU countries in this study exhibits a similar trend in tangibles and intangibles investments. Investments in tangibles are still traditionally higher than intangibles in Europe in comparison to the US[13]. Just as its investments in intangibles, Luxembourg invests more in tangibles than its neighbors relatively to GDP in the sample distribution. 13 % of GDP has been invested in tangibles on average between 1995 and 2010 in Luxembourg. Then Belgium follows with 11.7 % and the biggest European economy Germany ranks third in the middle of the distribution with 9.81 %. The Netherlands and France are situated in the two last positions in my European sample countries with an investment in tangibles that amounted 9.79 % and 9.17 % respectively of GDP.

Given that investments in tangibles are exceptionally larger in Europe than in the US, it is not really surprising that the ratio of intangible to tangible investment is significantly lower in Europe than in the US. Figure 9 below shows the contrast. The difference between Europe and the US is striking. The level of intangible investments is on average 1.43 times the level of tangible investments in US during the period 1995-2010. France and Netherlands display the best intangible to tangible ratio among the EU countries on study (0.80 and 0.79 respectively). Luxembourg, Germany and Belgium with respectively a ratio of 0.69, 0.67 and 0.65 perform the worst with a ratio less than half the level of the US.

Figure 9: Intangible to Tangible Ratio 1995-2010



The consequences of the greater tangibles investments than intangibles in Europe

[12]Data on tangibles investments are extracted from INTAN-invest.

[13]In fact the UK is the unique European country whose intangible investments rate has taken over its tangible investments and therefore invests more in intangibles than it does in tangibles on average since the late 90s

than in the US are also noticeable in graph 5 (in appendix) which shows the relative importance of tangibles and intangibles in the GFCF over 1995-2010. A similar pattern appears in figure 9. Around 60 % of US GFCF is constituted on average of intangibles and the rest of tangibles (40 %). The opposite occurred in Belgium (60 % of tangible GFCF share and 40 % for intangibles). Figures of Luxembourg and the other EU countries in the study range in the same order.

Comparing the relative levels of intangible and tangible investment in Japan and the US, Fukao et al. (2009) find also a low ratio of intangible to tangible investment in Japan. The authors argue that this small ratio may be due to differences in the financial system. In Japan financial institutions such as banks play a major role in the provision of corporate funds, and they typically require tangible assets as collateral to provide financing. As the financial system of the EU countries here in my sample seems to be more bank-oriented[14]. I suspect just as Fukao et al. (2009) that the difference in investment behavior between the EU countries in study and the US to be at least partially due to differences in the financial structure. As a result, EU firms have preferred to accumulate tangible assets which can be used as collateral and small firms may be hampered in their growth because they often possess insufficient tangible assets to increase borrowing. These mechanisms as a result of Japan's financial system are likely to be important reasons why the ratio of intangible to tangible investment is low in the EU countries. In any case the US economy seems to have taken the right track with a clearly move into a knowledge economy than its European partners and is likely to maintain a sustainable growth path.

4 THE STOCK OF INTANGIBLE CAPITAL

4.1 Constructing Intangible Capital Stock

An increasing number of national statistical offices in developed countries are publishing physical capital measures, usually gross capital stocks and/or net capital stocks. The difference between these two concepts is depreciation that is reflected in net capital stocks but not in gross capital stocks. But, just as investments in intangibles, data on the stocks of the overall intangible capital (as listed by CHS) does not appear at any time in national accounts. However data on intangible capital stocks exist at http://www.INTAN-Invest.net which provides cross country business market sector data on intangible assets for 27 EU countries plus Norway and the US. Unfortunately, data on the stock of intangible capital for Luxembourg are not available there. As the ultimate objective is to evaluate the impact of intangible capital in Luxembourg in the growth accounting framework, estimating the stocks of intangible capital are therefore necessary[15] . For the purpose at hand, therefore, I computed a series of net capital stocks for Luxembourg following the methodology usually employed in the literature (OECD, 2009)[16] . In what follows, I present a number of computational steps needed to transform the data on nominal intangible investments described in the previous section into the capital stocks. I use

[14]This is particularly evident in the case of Luxembourg.

[15]In fact, in some econometrics studies, it is not mandatory at all to construct intangible capital stocks in order to gauge its contribution to the output growth if we assume that in the steady state the growth rate of intangible stocks equal the rate of growth of investments in intangibles. Based upon this assumption we could then just replace intangible capital stocks by the investments rate. Obviously this is a strong hypothesis.

[16]See also Roth and Thum (2013), CHS, (2006), Baldwin et al. (2012), Marrano et al. (2009), Fukao et al. (2009) etc.

the Perpetual Inventory Method (PIM) to measure the stocks of intangible capital. It is of note that neither gross nor net capital stocks are the conceptually correct measure of capital input. Capital input is best captured by a measure of capital services. While measures of capital services have been constructed in previous studies (see van Ark et al. (2010), Marrano et al. (2009),Fukao et al. (2009)), computation of capital services measures has not been undertaken in the present paper. Recourse has therefore been taken to a simple measure of the net capital stock.

4.1.1 *Depreciation rates*

Depreciation is the loss of value of an asset due to aging and the rate of depreciation is asset specific. I use a geometric depreciation pattern for all intangible assets, which is also the common depreciation technique for the PIM in the literature. Relatively little is known about depreciation for intangibles, so I followed the assumptions of CHS (2012) by applying the values of depreciation rates δ shown in tab 3 in appendix.

Thus, despite the fact that I did not resort to capital services, applying these asset specific depreciation rates do capture some of the overall structure of capital by type of asset.

4.1.2 *Measuring initial intangible capital stocks*

Another issue with capital data is the measurement of the initial capital stock[17] . Capital stock growth rate depends crucially of the initial value set up. There are several approaches to measuring the initial capital stock. Two main methods are implemented in this paper: the first relies on past cumulative intangible investments and the second follows a simple procedure[18] that is based on the average growth of volume investment over a defined period of time.

- ***Initial intangible capital stocks from accumulating time series intangible investments***

The OECD (2009) estimates the initial stock using long-term series of investment that are accumulated based on the PIM. I follow the OECD approach. For the purpose at hand, the objective is to rely on intangible investment flows for early years as available. As this information is missing in the case of Luxembourg (series of intangible investment has been constructed starting from 1995), I try to extrapolate longer series of intangible investments back to 1985 based upon a functional relationship including models which covariates are internal and strongly correlated to intangible investments (GDP and lag GDP and intangibles covariates) and models which covariates are external (US R&D and Japan intangible investments)[19]. Nominal backward extrapolated intangible series are transformed into real series using the average EU countries intangible price deflators calculated based on nominal and real series on intangibles investments available at INTAN-invest website as existing data on intangible price deflators for Luxembourg is unavailable.

[17]This is in fact a dreaded task. Many papers usually do not give any detail on the computation of the initial capital sock and "hide" it in sort of black box.

[18]For more detail see Kohli (1982).

[19]Models include linear, log linear and dynamic intangible investments backward extrapolation.

Then, for each intangible asset type, I approximate initial net stocks at the beginning of the benchmark year t_0, which, in this study is 1995, by the cumulative depreciated investment of previous years starting in 1985.

$$R(t_0)_i = [N(t_0 - 1)_i + (1 - \delta_i)N(t_0 - 2)_i + (1 - \delta_i)^2 N(t_0 - 3)_i + ...] \quad (1)$$

The initial capital stock was set to zero for each asset in 1985. The assumption that initial capital stocks are set to zero rather than an unknown positive value has little effect in the growth accounting results presented in the next section. Given the relatively high depreciation rates of intangibles, most of each investment is depreciated away within five years, and so is the true value of the benchmark by the date I start the growth accounting analysis (1995). So it is sufficient to start the accumulation exercise in 1985.

- ***Formula for Setting the Initial Stocks***

Consider intangible asset i. According to the PIM which involves adding each year's investment in each type of intangible to the depreciated amount of the preceding year's capital stock,

$$R(t)_i = N(t)_i + (1 - \delta_i)R(t - 1)_i$$

The initial stock is derived as follows:

$$R(0)_i = \frac{N(0)_i}{(g + \delta_i)} \quad (2)$$

In equation 2 [20] , $R(0)_i$ represents the initial capital stock, $N(0)_i$ the amount of money invested in intangible asset i in the first year, δ_i is the depreciation rate and g is supposed to be the long-run growth rate of intangible investments. Given that the series of intangible investments are constructed from 1995 to 2012, I estimate the initial capital stock (that is at the beginning of 1995) for each type of intangible i and then sum up to derive the aggregate capital stock of intangibles as follows:

$$R(0) = \sum R(0)_i$$

- ***Estimating real net intangible capital stocks***

The next step in the calculation is to derive yearly net intangible capital stocks. This is done using the PIM based upon the computation of initial stocks or by accumulating real intangible investments year by year and by netting out depreciation for each asset i as follows[21]:

$$R(t)_i = N(t - 1)_i + (1 - \delta_i)N(t - 2)_i + (1 - \delta_i)^2 N(t - 3)_i + ...$$
$$+(1 - \delta_i)^{(T-1)} N(T - 2)_i + (1 - \delta_i)^T R(0)_i$$

[20] See also Baldwin et al. (2012).

[21] See OECD 2009 for a full discussion.

4.2 Descriptive Statistics

This subsection reports the estimates of the stock of intangibles in Luxembourg derived from the methodology described above. In 2012, the real value of Luxembourg intangible capital stock stood at 10,090 million euros[22]. Half of the stock of intangible capital (1995-2012) is dominated on average by innovative property of which R&D shares nearly two third. Then follows the stock of economic competencies which accounts for 40 % of the total intangible capital stock with organizational capital sharing the biggest part (70 %). The remaining part (10 %) of the stock of intangibles is shared by computerized information entirely constituted by software. The composition of the stock of intangibles by categories and assets is depicted by graph 6 and 7 in appendix[23].

Just as the investments, the trend of the overall stock of intangibles is upwards since 1995. However the rate of growth of the stocks of intangibles capitalized in the national accounts is much smaller as graph 8 in appendix shows. Graph 8 also displays the evolution of the stock of the overall CHS intangible estimated through the two methods described above (PIM to initial stock computed through the cumulative past estimates of intangible investments: method 1 and PIM to initial stock derived by the formula expression: method 2 which exhibit a nearly equivalent trend over time.

Compared to tangibles, the stock of the overall intangibles has increased less rapidly on average between 1996 and 2012. The stock of tangibles grew at an annual space of 6.12 % while the stock of intangibles increased at a speed of just 4.02 %. Moreover the growth of intangible capital has been slowing down since 1996 while tangible capital has been on the rise until the aftermath of the recent financial crisis. Across CHS categories, Economic competencies and Innovative property stocks grew the fastest at the annual rate of 4.67 and 4.08 % respectively. In contrast, the growth of computerized information stock has been flat at about 0.69 % between 1996 and 2012 (see table 3 below for more detail).

[22]This figure is given by applying the PIM to my preferred method of deriving the initial capital stock through the accumulation of the backward extrapolated estimates on intangible investments. The corresponding estimates using the formula expression is 10,101 million euro which is roughly the same.

[23]The dominance of innovative property in the composition of the stock of intangibles comparing to the investments composition where it ranks second after economic competencies group is due to the relatively high level of economic competencies depreciation rate.

Table 3: Growth rate of real stocks: Tangibles vs Intangibles

	1996-2000	2001-2005	2006-2010	1996-2012
Tangible	**5.91**	**6.53**	**5.93**	**6.12**
Intangible	**5.08**	**4.90**	**3.30**	**4.06**
Computerized Information	**3.88**	**11.70**	**-6.51**	**0.69**
Software	3.88	11.70	-6.51	0.69
Innovative Property	**4.91**	**3.77**	**4.39**	**4.08**
R&D	2.31	1.00	1.88	1.37
Architectural Design	11.11	9.87	7.41	8.50
Mineral Exploration & Arts	17.14	1.91	2.00	9.40
New Financial Product	11.77	10.97	10.93	10.48
Economic Competencies	**5.60**	**4.36**	**4.55**	**4.67**
Advertising	4.24	6.01	4.26	4.43
Market Research	0.60	-13.08	0.03	-0.92
Training	5.93	5.75	5.20	5.32
Organizational Capital	6.28	5.11	4.56	5.02

Source: Author's calculation

This section has been devoted to estimating Luxembourg stock of intangible capital necessary to implement the growth accounting. The next section describes the growth accounting framework to including intangible capital in a neoclassical production function. Results are then presented.

5 EMPIRICAL ANALYSIS OF THE CONTRIBUTION OF INTANGIBLE CAPITAL TO ECONOMIC GROWTH

Having successfully capitalized intangible investments, it is time to look at its contribution to Luxembourg economic growth. The methodology used here follow the literature in the country-specific study by applying the growth accounting procedure. I first recall the theoretical framework of the accounting methodology and then assess the effect of intangible capital on GDP and Labor Productivity Growth (LPG). The growth accounts are constructed over 1996 and 2012 and shorter time frames (five years span and periods before, during and after the 2008 financial crisis) excluding and including all intangibles as well as just taking into account intangibles traditionally capitalized in national statistics.

5.1 Theoretical Framework of the Contribution of Intangibles to Economic Growth

5.1.1 *The growth accounting methodology*

Growth accounting explains the different source of growth by providing the contribution to each factor input (Barro and Sala-i Martin, 2004). The starting point of the growth accounting methodology is the neoclassical aggregated production function (Solow, 1956)[24]

[24]The basics of growth accounting were also presented in, Kendrick (1961),Denison (1962), and Jorgenson and Griliches (1967)

$$Y_t = A_t F(K_t, L_t) \tag{3}$$

where A is the level of technology, K is the capital stock, and L is the quantity of labor.

Without knowing precisely the functional form of the production function $F(K_t, L_t)$, computing its total differential with respect to time allow isolating the contribution of each factor to the output growth.

Differentiating equation 3 totally with respect to time and then dividing by Y_t yields progressively:

$$\dot{Y}_t = \frac{\partial Y_t}{\partial A_t}\dot{A}_t + \frac{\partial Y_t}{\partial K_t}\dot{K}_t + \frac{\partial Y_t}{\partial L_t}\dot{L}_t$$

where $\dot{X}_t = \frac{\partial X_t}{\partial t}$

$$\dot{Y}_t = F(K_t, L_t)\dot{A}_t + \frac{\partial Y_t}{\partial K_t}\dot{K}_t + \frac{\partial Y_t}{\partial L_t}\dot{L}_t$$

$$\dot{Y}_t = F(K_t, L_t)\dot{A}_t + \frac{\partial Y_t}{\partial K_t}\frac{\dot{K}_t}{K_t}K_t + \frac{\partial Y_t}{\partial L_t}\frac{\dot{L}_t}{L_t}L_t$$

$$\frac{\dot{Y}_t}{Y_t} = \frac{\dot{A}_t}{A_t} + \frac{\partial Y_t}{\partial K_t}\frac{K_t}{Y_t}\frac{\dot{K}_t}{K_t} + \frac{\partial Y_t}{\partial L_t}\frac{L_t}{Y_t}\frac{\dot{L}_t}{L_t}$$

$$\Rightarrow \frac{\dot{Y}_t}{Y_t} = g + F_K\frac{K_t}{Y_t}\frac{\dot{K}_t}{K_t} + F_L\frac{L_t}{Y_t}\frac{\dot{L}_t}{L_t}$$

Where F_K, F_L are the factor marginal products and g the growth due to technological change is given by $g = \frac{\dot{A}}{A}$[25]

The following assumptions must hold:

- Firms are operating in perfect competition markets
- Factors are paid their social marginal products, so that $F_K = R$ (the rental price of capital) and $F_L = w$ (the wage rate)
- The computations typically assume that marginal products can be measured by factor prices.

$$finally \frac{\dot{Y}_t}{Y_t} = g + S_K\frac{\dot{K}_t}{K_t} + S_L\frac{\dot{L}_t}{L_t}$$

Where $S_K = rK/Y$ and $S_L = wL/Y$ are the respective shares of each factor payment in total product. The condition $S_K + S_L = 1$ or $Y = rK + wL$, must hold if all the income associated with the gross domestic product, Y, is attributed to one of the factors, restricted here to capital and labor. According to Barro and Sala-i Martin (2004), in an international context, some net factor income may accrue to foreign owned factors,

[25]This implicitly assumes that the technology progress appears in a Hicks-neutral way, so that $F(A, K, L) = A.F(K, L)$ and hence $g = \frac{\dot{A}}{A}$. g is interpreted as a measure of the Solow residual which is the growth rate of output unexplained by the growth rate of factors. g is often also regarded as an estimate of Total Factor Productivity (TFP).

and $rK + wL$ would include this net factor income. The equation of output, Y, to total factor income is consistent with equality between factors prices and marginal products if the production function, $F(.)$, exhibits constant return to scale in K and L, so that $Y = F_K K + F_L L$ holds.

5.1.2 *Integrating intangibles as a production factor*

The economic literature has traditionally stressed the role of tangible capital (physical capital) as an important source of economic growth. However, CHS, (2006) point that intangible capital may have considerable impact in determining the long-run growth. Thus integrating it in the production function is an important step towards measuring its contribution to economic growth. Following Solow-Jorgenson-Griliches (SOG) framework, CHS, (2006) expand the conventional growth accounting analysis to include intangible input. Suppose the growth accounting exercise conducted previously and assume now that the production function of equation 3 is specified as follows:

$$Y_t = A_t F(K_t^T, K_t^I, L_t) \tag{4}$$

Where Y_t represents GDP, A_t stands for multi-factor productivity (MFP) or total factor productivity (TFP), K_t^T is tangible capital, and K_t^I stands for intangible capital. L_t stands for labor input.

The same differentiation exercise as in equation (3) leads to:

$$g_Y(t) = s_L(t)g_L(t) + s_{K^T}(t)g_{K^T}(t) + s_{K^I}(t)g_{K^I}(t) + g_A(t) \tag{5}$$

Equation (5) suggests that the growth rate of output $g_Y(t)$ is equal to the weighted contributions from the growth in labor $g_L(t)$, tangible capital $g_{K^T}(t)$ and intangible capital $g_{K^I}(t)$ and multifactor productivity $g_A(t)$. The weights sum up to one ($s_L + s_{K^T} + s_{K^I} = 1$)

5.2 Contribution to GDP Growth

5.2.1 *Variables of interest and data sources*

The SOG model (equation 5) just described requires both the growth rate of factors input and their income share. The present subsection presents briefly the measures of the variables used as well as the data sources.

- ***Factors input***

Labor input

Hours actually worked by all persons engaged at the level of business sector are the conceptually preferred measure of labor input. In some studies, when total hours worked is missing, the hours worked of employees or workforce jobs and number of people in employment are used as proxy. Data on hours worked used in the present paper come from two sources: national statistics available from 2002 to 2012 and from EUKLEMS databases from 1995-2001.

However, the measure of total hours worked is an incomplete measure of labor input because it does not account for changes in the skill composition of workers over time, such as those due to higher educational attainment and work experience. Adjustment for such attributes would provide a more accurate indication of the contribution of labor

to production[26] . In the absence of these adjustments, as it is the case in this study, more rapid output growth due to a rise in skills of the labor force are captured by the MFP residual, rather than being attributed to labor. This should be kept in mind when interpreting rates of MFP growth.

Capital input

Capital is made up of the traditional tangible or physical capital and intangible capital. Measures of their stock are used in this study. I derived data on the stock of tangible capital by excluding the stock of intangible fixed assets capitalized in national accounts from the net capital stock of the overall produced assets available in national statistics. Data on the overall CHS intangible capital stock come from my estimates in section 4.

The drawback of using the relatively simplified approach of the stock of capital is that this neglects capital services. Capital services could differ unless the prices of all types of assets move at the same rate and each type of asset depreciates at the same rate which case is rather unrealistic. Therefore the appropriate measure for capital input in the growth accounting framework is the flow of productive services that can be drawn from the cumulative stock of past investments in capital assets. These services are estimated by the OECD using the rate of change of the "productive capital stock". For an overview of the technical steps in how intangible and tangible capital services are constructed, see the literature by Marrano et al. (2009) and Oulton and Srinivasan (2003).

- ***Factor Costs and Shares***

In order to estimate the income share of each factor input it is necessary to estimate the remuneration of total factors or total factor costs. Given the assumption of perfect competition and constant return to scale total revenues or income and total remuneration or compensation or costs are equal and therefore can be independently used. The total factor cost is made up of the labor costs and the user costs of the capital.

Labor costs

National accounts provide information on the remuneration of employees. However, labor income of the self-employed is approximated by the average remuneration per employee multiplied by the number of self-employed as it comprises both labor and capital income accruing to the self-employed. Average remuneration per employee is measured as compensation of employees as defined in the System of National Accounts, including all costs for employers such as their contributions to the employee's social security. The data on total labor compensation of this study is extracted from the OECD productivity databases.

The user cost of the capital

Either tangible or intangible, capital compensation is measured by the user cost as the product of unit user cost and the net capital stock. The standard expression for the unit user cost of any asset was derived by Jorgenson (1963) as follows:

$$P_i(t) = [r(t) + \delta_i(t) - \pi_i(t)]d_i(t)$$

Where $r(t)$ is a measure of the net rate of return common to all capital in year t , $\delta_i(t)$ is the depreciation rate for asset i at time t[27] ; $\pi_i(t)$ is the expected capital gain (loss) on asset i, and $d_i(t)$ is the asset investment price deflator.

[26]For an adjusted labor input measure and labor quality see Jorgenson et al. (1987).

[27]Recall that the depreciation rate used in this paper is asset specific but constant over time (see tab 3 in appendix).

For simplicity, I consider that the unit user costs are composed of a real rate of return, a constant rate of depreciation (even for tangibles) and the investment deflator. The user cost of capital for asset i, U_i is therefore given as[28]:

$$U_i(t) = d_i(t)[r(t) + \delta_i]K_i(t)$$

The OECD investment deflator at market price series $d_i(t)$ has been used to derive the user costs of tangibles and intangibles user costs have been calculated based on the deflator series explained in section 4 while transforming nominal intangibles series to real series. Also data on $r(t)$ come from the OECD and correspond to the annual long-term interest rate on government bonds. For the rate of return, I assumed the same rate for tangible capital as for intangible capital (see CHS, 2006)[29] . Finally a weighted depreciation rate of the aggregated tangibles has been computed for Luxembourg based upon the depreciation rate of each type of tangible asset available for the US, Canada and Japan in the OECD manual (2009) "Measuring Capital".

Factor shares

The next link in completing the data needed for the SOG is the estimation of factor shares. They are obtained by dividing each factor costs by the total factor costs which is made up of the sum of total labor costs, tangible and intangible user costs.

All the elements needed to construct growth accounts gathered, I present next the results from estimating the SOG equation (5).

5.2.2 *Results from growth accounting*

- ***Growth accounting: Output basis***

The first series of results are reported in table 4 which shows the contributions of labor, MFP, tangible and intangible to GDP growth in Luxembourg business sector. The accounting results are presented for different time period and different SOG models. I consider first a five years span analysis (1996-2000, 2001-2005 and 2006-2010) which accounts for the dynamics of the contribution of each factor of production. Then I try to gauge the effects of the recent 2008 financial turmoil by examining the results before (2005-2007), during (2008-2009) and after (2010-2012) the crisis. Results of the overall period of analysis (1996-2012) are also reported. The SOG models into consideration include SOG without any intangibles (top panel of table 4), the SOG including the overall aggregated CHS intangibles (middle panel of table 4) and the SOG with intangibles that only appear in the national accounts (bottom panel of table 4). The items listed under the heading "contribution of factor" are the growth rate of each input weighted by the corresponding factor share. In moving from one formulation to the other, I make appropriate adjustments to factor shares.

[28]The capital gain term is proxied by the three-year moving average of changes in the non-farm business price deflator (CHS, 2006)

[29]Of course, the rates of returns can vary, depending on the risk. Since investment in R&D for example is riskier than investment in tangible capital, the expected rate of return on R&D capital is higher than on tangible capital. I have abstained from additional complexity in the computations here.

Table 4: Growth Accounting : Real GDP Basis (percentage points)

	Five years			Before, During and After the financial crisis			Whole period
	96-00	**01-05**	**06-10**	**05-07**	**08-09**	**10-12**	**96-12**
(a)Contribution of Factor: Excluding All Intangibles							
Real Output Growth	5.83	3.44	1.74	5.48	-2.96	1.60	3.34
Labor	2.78	1.43	1.55	2.05	0.75	1.33	1.86
Tangible Capital	2.07	2.24	2.34	2.51	2.43	2.18	2.24
TFP	0.97	-0.22	-2.15	0.92	-6.14	-1.91	-0.77
(b)Contribution of Factor: Including All intangibles							
Real Output Growth	6.03	3.54	1.30	5.30	-3.15	1.37	3.31
Labor	2.49	1.27	1.40	1.84	0.68	1.22	1.67
Capital Deepening	2.39	2.53	2.43	2.79	2.43	2.11	2.44
Tangible Capital	1.85	2.00	2.11	2.26	2.19	1.99	2.02
Intangible Capital	0.54	0.52	0.32	0.52	0.24	0.12	0.42
TFP	1.14	-0.26	-2.53	0.67	-6.26	-1.96	-0.80
(c)Contribution of Factor: Intangibles Included in National Accounts							
Real Output Growth	5.95	3.53	1.54	5.44	-3.26	1.60	3.34
Labor	2.74	1.40	1.51	2.00	0.73	1.31	1.83
Capital Deepening	2.31	2.37	2.42	2.76	2.40	1.94	2.34
Tangible Capital	2.04	2.20	2.28	2.45	2.37	2.15	2.20
Intangible Capital	0.27	0.17	0.14	0.31	0.04	-0.21	0.14
TFP	0.90	-0.25	-2.39	0.68	-6.39	-1.65	-0.83

Notes: Note: Items may not add up to totals due to independent rounding error and averages.
Source: Author's calculation

A number of conclusions can be drawn from a comparison of the three panels.

First, I found that accounting for all intangible assets seems not to have any impact on the GDP growth for the overall period from 1996 to 2012. The growth rate of GDP has even slightly decreased by 0.03 percentage points (from 3.34 % to 3.31 % in the last column of table 4) compared to the results that exclude totally any intangibles from the accounting analysis and those that only include intangibles capitalized in the national accounts. This sharp contrast to the overall positive effect of capitalizing wider range of intangibles in previous studies may be puzzling. Investigating the puzzle I found that intangible investment has contributed less to the level of output over the course of the entire period of 1996-2012. The growth of output was slower with intangibles than without, likely because the pace of intangibles expansion is less over the period. More precisely the growth rate of aggregate intangible investments have been lower than the conventional GDP rate of growth which just takes into account software and mineral exploration & arts intangibles and the GDP growth that excludes any types of intangible.

However, examining the results for some shorter time frames reveal some contrasting conclusions. It is apparent that the inclusion of all CHS intangible assets picked up the output growth in the second half of the 1990s (first column of table 4). The growth rate of GDP has accelerated by about 0.20 percentage point per annum (pppa) between 1996

and 2000 in comparison to the top panel where intangibles are excluded and by 0.08 pppa compared to the bottom panel which just includes intangibles capitalized in the national accounts. A similar pattern is observable in the early 2000s (period 2001-2005) though the speed up slowed down at about 0.10 pppa when compared to the exclusion of any type of intangibles and just 0.01 when the comparison relates to intangibles included in national statistics. A possible explanation of these results is that intangible investments grew more rapidly than the conventional GDP growth (bottom panel) and the growth of GDP that excludes intangibles (top panel) in the late 1990s and early 2000s. Therefore the inclusion of the overall more dynamic CHS intangibles speeds up the growth of the output. But just as the results of the entire period of analysis (1996-2012), accounting for all CHS intangibles seems to have had a negative impact at the heart of the 2008 financial turmoil. The recession triggered by the crisis was more pronounced when all intangibles are accounted for than excluding them (GDP grew at -2.96) which again suggests a greater fall in growth of intangibles than the drop of output growth. The dependence of growth accounting estimates on the period of analysis is a well-known characteristic of this type of analysis. Nonetheless, these first results suggest that intangible investment seems to be an important driver for economic growth in Luxembourg as my accounting exercise shows. Speeding up the rate of growth of intangibles might have a positive effect on GDP growth while its slowdown risks affecting badly a sustained long run growth of the economy.

Second, consider the relative importance of the factors explaining growth changes when all CHS intangibles are introduced. Adding all CHS intangibles to the accounting exercise increases in general capital deepening. Between 1996 and 2012 capital deepening accelerated by 0.20 pppa at 2.44 % annual growth when counting for intangibles than excluding them. Comparing to intangibles capitalized in national statistics the acceleration is lower (0.10 pppa). The increase of capital deepening is also almost observable in shorter time frames with a bigger increase when all intangibles appear in national accounts. There are two possible explanations for this. Recall that capital deepening is the product of the capital share and growth rate of capital stock. When adding all CHS intangibles, the share of capital goes up and therefore, ceteris paribus, capital deepening rises. As adding new capital assets changes the weights and so the growth of capital stock could, in theory, rise, remain the same, or fall. Capital plays a larger role in accounting for GDP growth once all intangibles are included. Between 1996 and 2012, capital accounted for around 74 % of output growth when intangibles are included, but only 67 % when they are excluded and 70 % when counting for those that appear in national accounts. This result is in line with previous studies which found a more important role of capital in explaining economic growth when intangibles are taking into account (Corrado et al., 2006; Fukao et al., 2009; Marrano et al., 2009; Jalava et al., 2007). Examining the contribution of intangible capital to economic growth in Luxembourg, I come to the following conclusions: taking the whole period of analysis (1996-2012), the portion of top line growth of table 4 explained by intangibles goes from 0 % in the top panel (by definition) to 4 % with a small part of them (bottom panel) and up to around 13 % with all of them (middle panel). The corresponding numbers for the contribution to the overall capital deepening are 0 %, 6 % and 17 %, respectively over the same period of time. Looking at the dynamics of the contribution of intangible capital to Luxembourg GDP growth, through shorter time periods of analysis (five years span), I notice that this has been falling over time. Thus, the contribution of intangible capital to output growth exhibited a slowdown. It was highest in the late 1990s (0.54 pppa). Then it slightly

reduced in the early 2000s (0.52 pppa) and dropped to 0.32 pppa in the last five years of 2000. The technology boom in the second half of the 1990s and the subsequent bust that follows in 2001 plus the recent 2008 financial crisis might account for the downward contribution of intangible capital to GDP growth in Luxembourg.

Third, consider the other sources of growth. Given their traditional role and relative abundance, it does not come as a surprise that labor and physical capital input explain the largest part of output growth. However, they seem to contribute less to the rate of growth of output when intangibles are accounted for though they still drive GDP growth the greatest. Labor and tangible inputs GDP growth contribution are greater when intangibles are excluded (1.86 pppa and 2.24 pppa respectively) than partly included (1.83 pppa and 2.20 pppa respectively) and completely included (1.67 pppa and 2.02 pppa respectively) between 1996 and 2012. Examining the last source of growth that is MFP, it can be noticed that its contribution turned out to be negative in each of the top middle and bottom panel of table 4 for the total economy over the entire period of study. Comparing MFP growth rates of the top and middle panel of table 4 reveals that this source of growth declines in absolute importance either in the longer period (1996-2012) or any shorter time period at the exception of the late 1990s where MFP stood up higher. A similar conclusion can be drawn when comparing the top to the bottom panel. MFP tended to decrease over the periods of study. This result is not particularly surprising in light of Jorgenson et al. (1987) and in view of the fact that MFP is measured as a residual. In line with the finding of Jalava et al. (2007), capitalizing intangible investments decreases the measure of our ignorance.

Graphs 9 through 11 in appendix graphically present the results from table 4. Graph 9 shows the contribution of all contributors to GDP growth in accordance to the top panel results of table 4 while graphs 10 and 11 display the corresponding results of the middle and bottom panel of table 4.

- ***Contribution of intangibles to GDP growth by CHS category***

In table 5, I continue the SOG results of table 4 by breaking down the contribution of intangible capital to GDP found in the middle panel of table 4 into separate CHS categories of computerized information, innovative property and economic competencies. Apparently the largest contribution to consolidated output stemmed from economic competencies and, more precisely, organizational capital which account for the largest to the GDP contribution of this category. Economic competencies capital contributed to more than two third of the contribution of overall intangible capital to Luxembourg growth at 0.27 pppa during the whole period of analysis. The major driver of economic competencies contribution comes from organizational capital (more than 70 % of the economic competencies capital contribution to GDP) followed by training, advertising and market research (22,7 % and 1 % respectively). The second biggest GDP growth contributor among CHS decomposition is innovative property which accounted for around 30 % of total intangibles contribution to the economy growth at 0.13 pppa. Architectural design contribute for the most to innovative property GDP contribution (more than half) followed at equal importance of scientific R&D and new product development and mineral exploration. Computerized information which is made totally by software capital in the case of Luxembourg contributes the least (only 7 %) to the overall intangibles contribution to economic growth at 0.03 pppa.

It is perhaps surprising that scientific R&D is found to have a rather small role in light of the attention that it has been given in the literature of innovation but it is probably

more surprising that organizational capital for the same reason that it never received any attention, though, is found to play the greatest role in contributing to economic growth compared to any other intangible asset type and by far cry R&D capital[30].

Table 5: Contribution of Intangible Capital to GDP Growth

	Five years			Before, During and After the financial crisis			Whole period
	96-00	**01-05**	**06-10**	**05-07**	**08-09**	**10-12**	**96-12**
Computerized Information	**0.04**	**0.16**	**-0.06**	**0.07**	**-0.12**	**-0.10**	**0.03**
Software	0.04	0.16	-0.06	0.07	-0.12	-0.10	0.03
Innovative Property	**0.17**	**0.12**	**0.13**	**0.16**	**0.12**	**0.06**	**0.13**
R&D	0.06	0.02	0.03	0.05	0.02	-0.01	0.03
Architectural Design	0.08	0.09	0.07	0.08	0.08	0.02	0.07
Mineral Exploration & Arts	0.02	0.00	0.00	0.01	0.00	0.02	0.01
New Financial Product	0.03	0.03	0.04	0.04	0.04	0.03	0.03
Economic Competencies	**0.34**	**0.28**	**0.25**	**0.30**	**0.23**	**0.17**	**0.27**
Advertizing	0.02	0.03	0.02	0.03	0.01	0.01	0.02
Market Research	0.02	0.00	0.00	-0.01	0.01	0.04	0.01
Training	0.07	0.06	0.06	0.07	0.05	0.04	0.06
Organizational Capital	0.24	0.20	0.17	0.21	0.16	0.10	0.19

Notes: Note: Items may not add up to totals due to independent rounding error and averages.
Source: Author's calculation

The results of table 5 are displayed in graphs 12 and 13 in appendix. Undoubtedly economic competencies capital represents the biggest intangible capital CHS component contributor of which organizational capital is the main driver.

5.3 Contribution to Labor Productivity Growth (LPG)

The analysis of the previous section focused on the contribution of factor inputs to Luxembourg GDP growth stressing the role of intangibles. In this subsection, I turn my attention by analyzing another key variable of economic development that is Labor Productivity Growth (LPG) still in the SOG framework. Again the emphasis is being made on the contribution of intangible capital.

5.3.1 *Variables of interest*

Assume the following Cobb Douglas production function:

$$Y_t = A_t(K_t^T)^{\alpha_t}(K_t^I)^{\beta_t}L_t^{1-\alpha_t-\beta_t} \tag{6}$$

[30]In fact this result is not surprising at all given that organizational structure is found to be the most important factor driving the growth of the total intangible investment variable in section 3 as it is the faster growing type of intangibles and represent the largest total intangible share.

Where Y_t, A_t, K_t^T, K_t^I and L_t stands just as in equation 4. α_t and β_t represent the share of each factor cost (tangible and intangible) in the total factors costs. Taking the ratio of GDP to labor input to have measure of labor productivity[31] and then log differentiating yields the following expression:

$$\Delta y = \Delta a + \alpha \Delta k^T + \beta \Delta k^I \tag{7}$$

Where $\Delta x = \frac{\partial ln(X_t/L_t)}{\partial t}$, and $x = ln(X_t/L_t); (x = y, k^T, k^I)$. Moreover a is the logarithm of A. Δx is a differentiating log of x and can therefore be interpreted as a growth rate of x. According to equation 7, LPG is made up of the sum of the weighted capital (tangible and intangible) to labor ratio growth and the Solow residual. From equation6 and 7, I obtain equation 8

$$\Delta lnY = \Delta y + \Delta lnL \tag{8}$$

which breaks up the overall GDP growth with the contribution of LPG and labor input growth. Equation 7 reveals the necessary variables which enter in the LPG accounting. There are: tangible-labor ratio growth, intangible-labor ratio growth and TFP. Of course factor shares also are needed in the present accounting exercise. But they are the same as determined in the previous subsection.

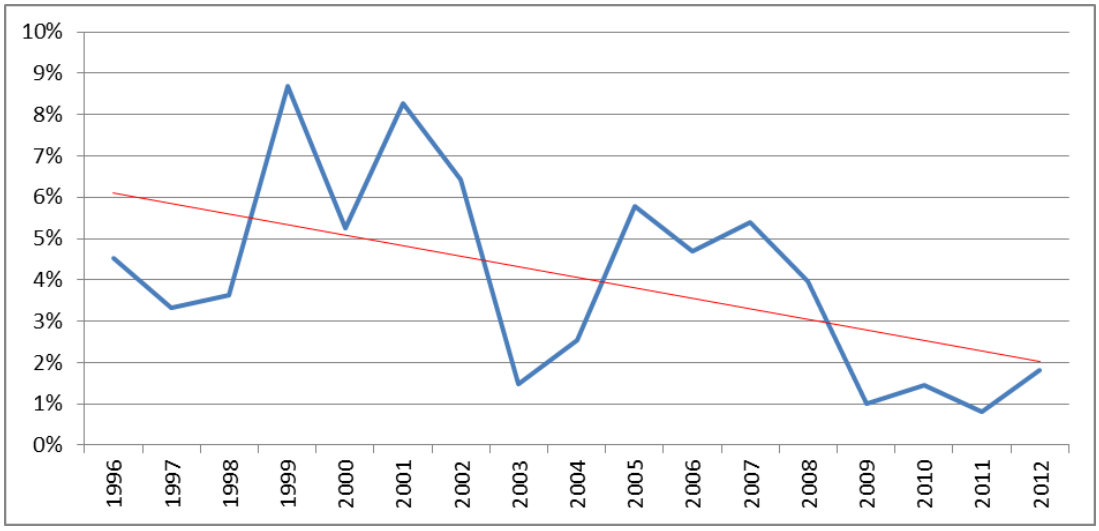
5.3.2 *Results from growth accounting*

- ***Contribution of total intangible to LPG***

Results for the contributions to LPG are shown in table 6 which is presented in the shape of table 4 i.e ignoring and accounting any intangible asset type (panel a and b respectively) and taking into account only intangible assets that are included in national statistics (panel c). The main findings are quite similar to what I obtained in table 4. First treating spending on intangibles as capital input rather than as intermediate expenditure seems not to make any significant difference in the observed patterns of Luxembourg labor productivity growth between 1996 and 2012. Just as the results on GDP, labor productivity growth decreases slightly in the same magnitude by 0.03 pppa when all asset types of intangibles are capitalized compared to the situation where they are completely excluded. The slowdown in the accumulation and ceasing of the creation of intangible capital over the period are to blame (see figure 10).

[31] The OECD defines it as "the ratio of a volume measure of output to a volume measure of input"

Figure 10: Annual growth rate of intangible capital 1996-2012



The ability of intangible investments in raising LPG is shown in the first column of table 6 which covers the period 1996-2000. There, we observe a rapid expansion of intangible capital accumulation which translates into an acceleration of LPG. Compare to panel c where only few assets of intangibles are accounted for, capitalizing the full list of intangibles speeds up the rate of growth of labor productivity by around 0.07 pppa on average. In the hypothetical situation where intangibles are ignored (panel a), a complete capitalization of intangibles in panel b speeds up even more LPG at nearly 0.20 pppa on average. This result clearly shows the potential of a rapid increase in the accumulation of intangible assets in speeding Luxembourg LPG. Second, the inclusion of all intangible asset types in national statistics seems to deepen over all capital and its contribution to labor productivity growth as observed in the periods 1996-2000, 2001-2005 and 2005-2007 in comparison to panel a. However, the contribution of capital deepening to LPG appears to be more important on average when only few intangibles are accounted for (panel c) than counting fully all of them (panel b). Third, just as I found in table 4 in the analysis of GDP growth, the contribution of intangible capital to LPG are rather small in comparison to tangible capital. Intangibles contributed to 0.12 pppa to LPG whilst the contribution of tangibles stands nearly 9 times greater at 1.02 pppa.

Table 6: Growth Accounting: Labor Productivity Basis (percentage points)

	Five years			Before, During and After the financial crisis			Whole period
	96-00	**01-05**	**06-10**	**05-07**	**08-09**	**10-12**	**96-12**
(a)Contribution of Factor: Excluding All Intangibles							
GDP Growth	5.83	3.44	1.74	5.48	-2.96	1.60	3.34
Labor	4.28	2.17	2.55	3.30	1.25	2.23	2.93
LPG	1.55	1.27	-0.81	2.17	-4.21	-0.62	0.41
Capital deepening	0.57	1.49	1.34	1.25	1.92	1.29	1.18
TFP	0.97	-0.22	-2.15	0.92	-6.14	-1.91	-0.77
(b)Contribution of Factor: Including All intangibles							
GDP Growth	6.03	3.54	1.30	5.30	0.05	1.37	3.31
Labor	4.28	2.17	2.55	3.30	2.45	2.23	2.93
LPG	1.74	1.37	-1.25	2.00	-2.41	-0.85	0.38
Capital deepening	0.60	1.63	1.28	1.33	1.55	1.11	1.18
Tangible Capital	0.51	1.33	1.21	1.13	1.46	1.18	1.06
Intangible Capital	0.09	0.29	0.07	0.20	0.09	-0.07	0.12
TFP	1.14	-0.26	-2.53	0.67	-3.96	-1.96	-0.80
(c)Contribution of Factor: Intangibles Included in National Accounts							
GDP Growth	5.95	3.53	1.54	5.44	-3.26	1.60	3.34
Labor	4.28	2.17	2.55	3.30	1.25	2.23	2.93
LPG	1.67	1.35	-1.01	2.14	-4.51	-0.63	0.42
Capital deepening	0.77	1.60	1.38	1.46	1.88	1.03	1.24
Tangible Capital	0.57	1.47	1.31	1.23	1.88	1.27	1.16
Intangible Capital	0.21	0.13	0.08	0.23	0.00	-0.24	0.09
TFP	0.90	-0.25	-2.39	0.68	-6.39	-1.65	-0.83

Notes: Note: Items may not add up to totals due to independent rounding error and averages.
Source: Author's calculation

Again, as in the previous GDP accounting, the results of table 6 are shown graphically. Graphs 14, 15 and 16 in appendix respectively display the results of panel a, panel b and panel c.

- ***Contribution of intangibles to LPG by CHS category***

As previously done for GDP growth variable (table 5), I present in a last series of results, the contribution of each category and intangible asset type to LPG. The findings are reported in table 7 and the corresponding graphs 17 and 18 in appendix. The results are quite similar to those found in table 5. Economic competencies which growth is essentially driven by organizational capital is the major CHS component of intangible that contributes for the largest to LPG followed by innovative property and computerized information.

Table 7: Contribution of Intangible Capital to LPG

	Five years			Before, During and After the financial crisis			Whole period
	96-00	**01-05**	**06-10**	**05-07**	**08-09**	**10-12**	**96-12**
Computerized Information	**0.00**	**0.13**	**-0.09**	**0.02**	**-0.13**	**-0.11**	**0.00**
Software	0.00	0.13	-0.09	0.02	-0.13	-0.11	0.00
Innovative Property	**0.02**	**0.05**	**0.06**	**0.06**	**0.09**	**0.00**	**0.04**
R&D	-0.05	-0.02	-0.01	0.00	0.00	-0.04	-0.03
Architectural Design	0.05	0.07	0.05	0.04	0.07	0.00	0.05
Mineral Exploration & Arts	0.02	0.00	0.00	0.00	0.00	0.02	0.01
New Financial Product	0.02	0.03	0.03	0.03	0.04	0.02	0.02
Economic Competencies	**0.08**	**0.14**	**0.11**	**0.11**	**0.16**	**0.06**	**0.10**
Advertizing	0.00	0.02	0.01	0.02	0.01	0.00	0.01
Market Research	-0.01	-0.01	0.00	-0.02	0.00	0.03	0.00
Training	0.02	0.04	0.03	0.03	0.04	0.01	0.03
Organizational Capital	0.08	0.12	0.07	0.08	0.11	0.02	0.08

Notes: Note: Items may not add up to totals due to independent rounding error and averages.
Source: Author's calculation

5.4 Cross-Country Comparison of the Contributions of Intangible Capital to LPG

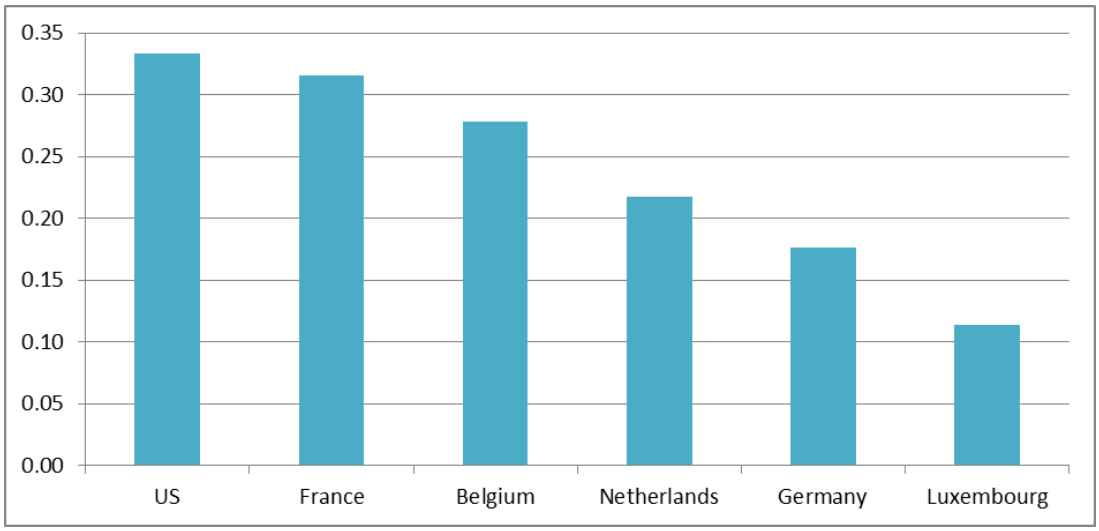
Although Luxembourg invests more in intangibles relatively to GDP, intangibles account only for a smaller part of the market sector LPG in Luxembourg in comparison to its neighbors and the Netherlands. From 1995-2007, intangible capital has contributed to just 11% to LPG in Luxembourg whereas the contribution in France, Belgium, The Netherlands and Germany was significantly larger (respectively 32%, 28%, 22%, 18%). The contribution to the US LPG is much bigger in the same period (33%). Table 8 and figure 11 illustrate the difference in LPG contribution of intangible capital in the country sample. Tab 4 and graph 19 in the appendix compares the absolute and relative breakdown contributions from computerized information, innovative property and economic competency to labor productivity across the sample countries over the same period of 1995-2007. Significant differences emerge between France Germany and Luxembourg. The important CHS component contributor to LPG in France is computerized information while in Germany it is innovative property. In Luxembourg Economic competencies contribute the most to LPG.

Table 8: Contributions of intangibles to the growth of output per hour, 1995 to 2007

	Labor Productivity Growth	Contributions of Intangibles	
		Absolute	Relative
Belgium	1.80	0.50	0.28
France	1.90	0.60	0.32
Germany	1.70	0.30	0.18
Luxembourg	1.49	0.17	0.11
Netherlands	2.30	0.50	0.22
US	2.70	0.90	0.33

Source: Corrado et al. 2012 and Author's calculation

Figure 11: Comparison of the Contributions of Intangible Capital to LPG 1995-2007



6 CONCLUSION

This paper has tried to understand better the impact of the "knowledge economy" on recent Luxembourg economic performance. It was concerned with the role of intangible capital in Luxembourg economy. The main findings are as follows:

First, despite having the highest level of investments in intangibles in relation to GDP among its neighbors and The Netherlands on average between 1995 and 2010, the pace of accumulation of intangible capital in Luxembourg has been declining since 1995 whilst the opposite is occurring in the neighboring countries and other major advanced economies (US, UK, Canada, Netherlands, Finland etc.) except for Japan which intangible capital growth rate is also on a downward trend and has been decreasing since the late 1980s because of its long term stagnation. Economic competencies, at about 57 % of total intangible investment between 1995 and 2012, are the largest part of intangible investment in Luxembourg and organizational capital is the biggest sub-group of economic competencies (two third). Then, follows innovative property (33 %) of which R&D is

the main component (55 %). Made up entirely by software expenditures, computerized information is the smallest part of intangible investment (10 %).

Second, intangibles accounted for around 13 % on average to annual output growth between 1996 and 2012. The contribution to LPG was much bigger (around 32%). But the impact of intangible capital has been slowing down over time due to the decreasing trend in the pace of accumulation of intangibles. Intangible capital contribution to GDP growth for instance was highest in the late 1990s (0.54 pppa), then slightly reduces in the early 2000s (0.52 pppa) and drops to 0.32 pppa in the last five years of 2000. Comparing to its neighbors and The Netherlands, Luxembourg has exhibited lower impact of intangible capital over the period 1995-2007. Intangible capital has contributed to 32% of LPG in France, 28% in Belgium, 22% in The Netherlands and 18% in Germany. The figure stood at only 11% in Luxembourg.

Third, a full capitalization of intangibles assets in national statistics does not raise apparently the rate of growth of output and labor productivity as expected from previous empirical studies. GDP growth and LPG were slightly slower with intangibles than without over the period 1996 and 2012 which is quite staggering in light of the potential positive effects that innovation received in the literature. Investigating this apparent slowdown of output and labor productivity when all types of intangible assets are accounted for, reveals that the downward trend of intangible capital accumulation over the entire period of analysis (1996-2012) is to blame. In booming times like the technological revolution we observe in the second half of the 1990s, the rapid accumulation of intangible assets has accelerated GDP and labor productivity growth more than any other periods of analysis considered in this study. That intangibles, and more generally, knowledge capital expansion is an important driver of modern economic growth is not challenged by the present findings. Indeed, a rapid creation of intangible assets and continued investment are a key part of keeping the growth of Luxembourg economy on track.

Fourth, labor and physical capital remain by far cry the major contributors of economic growth in Luxembourg. I believe that the relative important contribution of traditional neoclassical factor inputs especially the crushing dominant contribution of tangible capital compared to intangibles might be at least partly due to the bank based financial system in Luxembourg which does not recognize intangible assets as collateral. This hampers the growth opportunities of firms which hold few tangible assets because of the rising difficulties in obtaining external finance they face. Therefore, it would be helpful to introduce a new accounting system that aids the valuation of intangible assets because Luxembourg cannot rely on the traditional factors of labor and physical capital alone to promote sustained economic growth.

This study is in progress and much more remains to be done.

The labor input measure used in the paper is unadjusted for differences in skills and education which reflect labor quality.

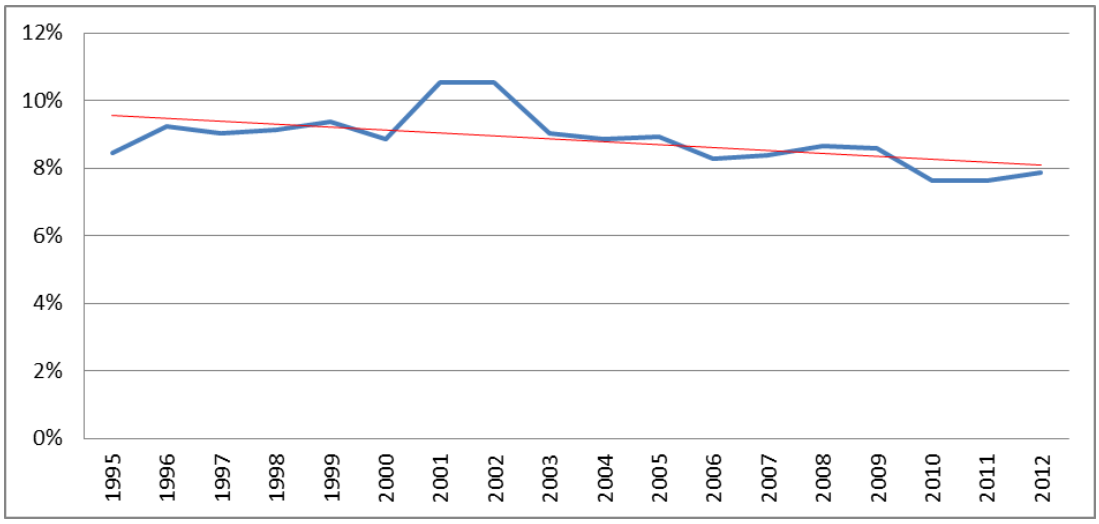
Capital stocks were used rather than capital services in the growth accounting analysis. The former takes no account of differences in the relative productivity of different types of assets, the latter does and constitutes the conceptually preferable measure of capital input. For the time being, however, this paper has to rely on the simplified stock approach.

While my analysis has been conducted at the overall commercial or business sector level, recent studies on the contribution of intangible capital has shed light in the scarce literature on the role of intangible assets for growth at a more disaggregated sectors (manufacturing and services) by measuring and documenting differences in intangible

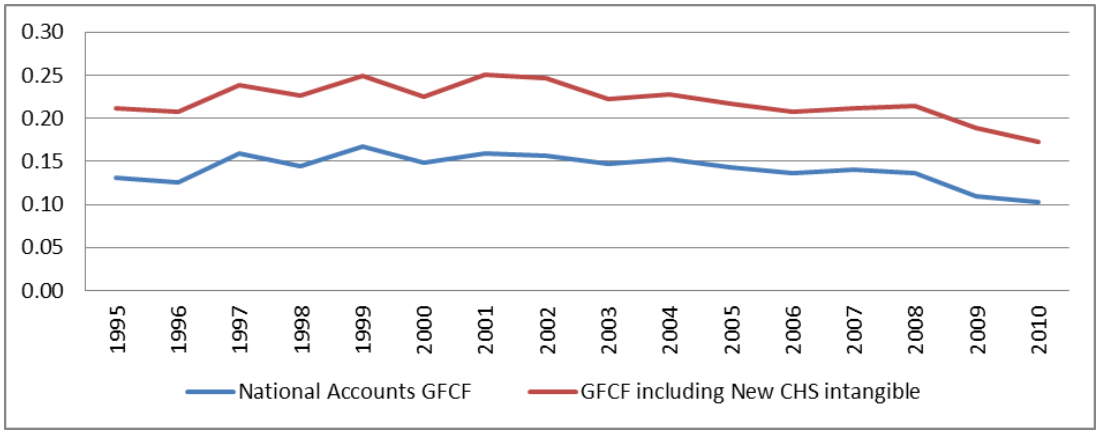
investment patterns across sectors. In the absence of suitable data for such analysis, for now, I leave it as a future exercise which will hopefully improve my results. Future tasks will also contribute to the emerging econometric literature on the relationship between intangibles and growth as the number of observations available for econometric analysis expands. Beside, recent development by van Ark et al. (2010) highlights the potential of public intangible investments in raising permanently the Dutch GDP growth: a subject of much interest for Luxembourg already included in my future research agenda.

Appendix A: Additional figures

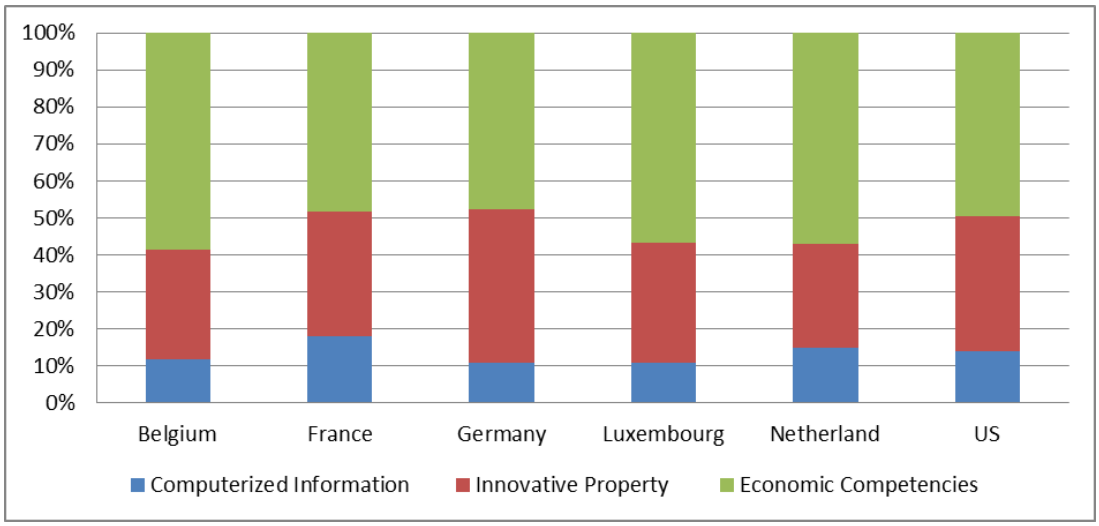
Graph. 1: Intangible GDP Share in Luxembourg



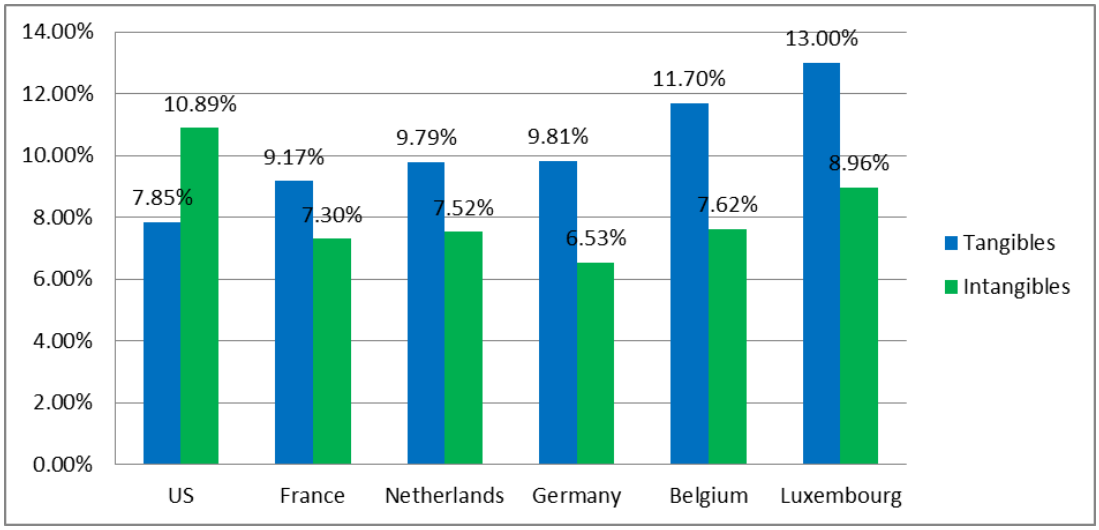
Graph. 2: Nominal GFCF GDP share



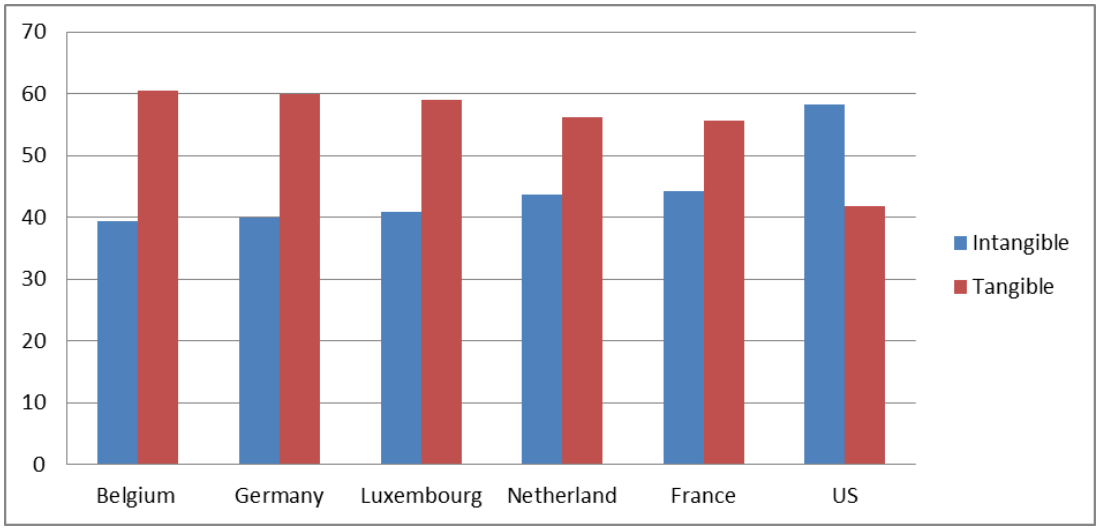
Graph. 3: Composition of Intangible Investment by CHS Components 1995-2012 (% of total intangible investment)



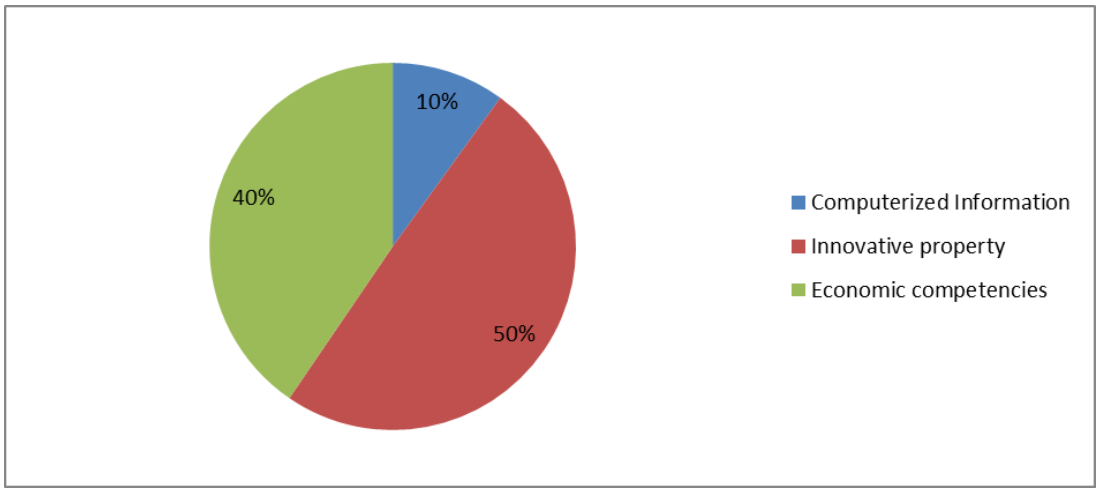
Graph. 4: Tangible vs Intangible GDP Share: 1995-2010 (average values)



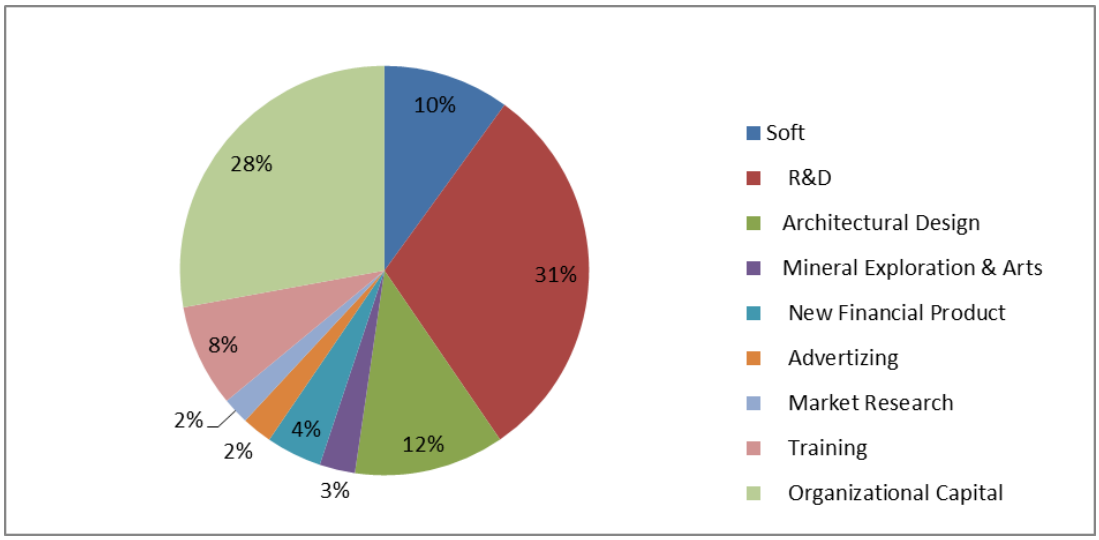
Graph. 5: Tangible and Intangible Total GFCF Shares 1995-2010



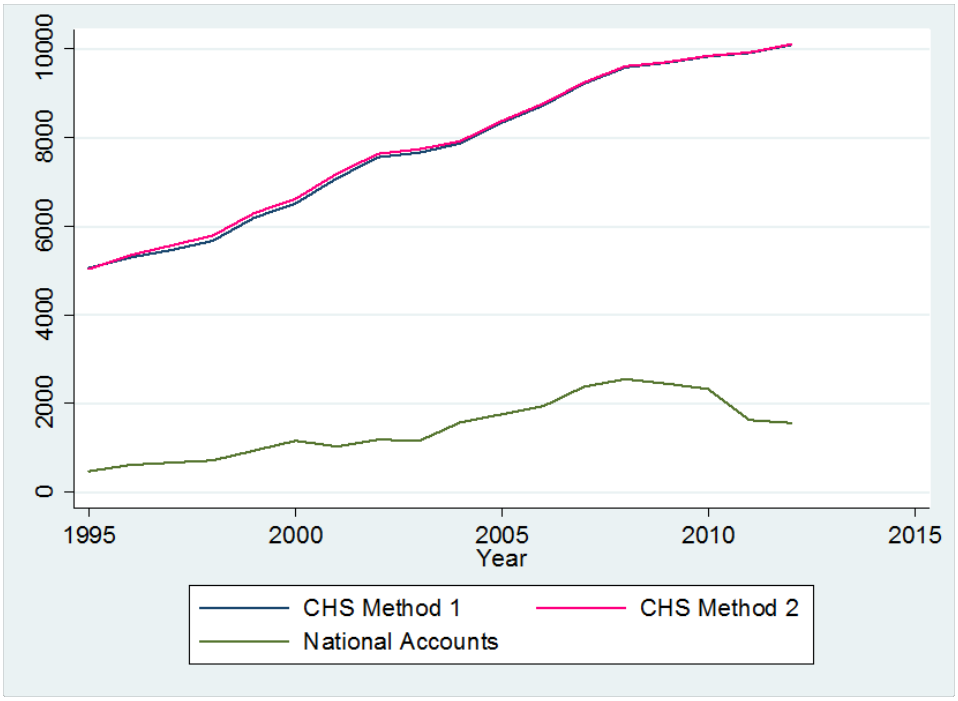
Graph. 6: : Composition of Real Intangible Stock by CHS Components 1995-2012 (% of total real intangible stock)



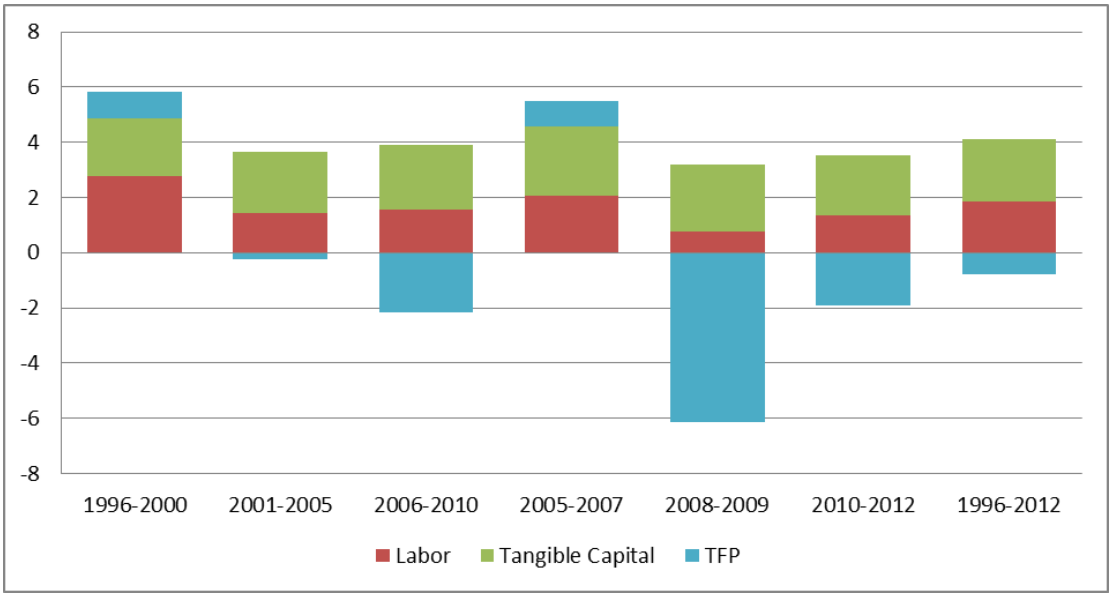
Graph. 7: Composition of Real Intangible Stock by CHS Sub-components 1995-2012 (% of total real intangible stock)



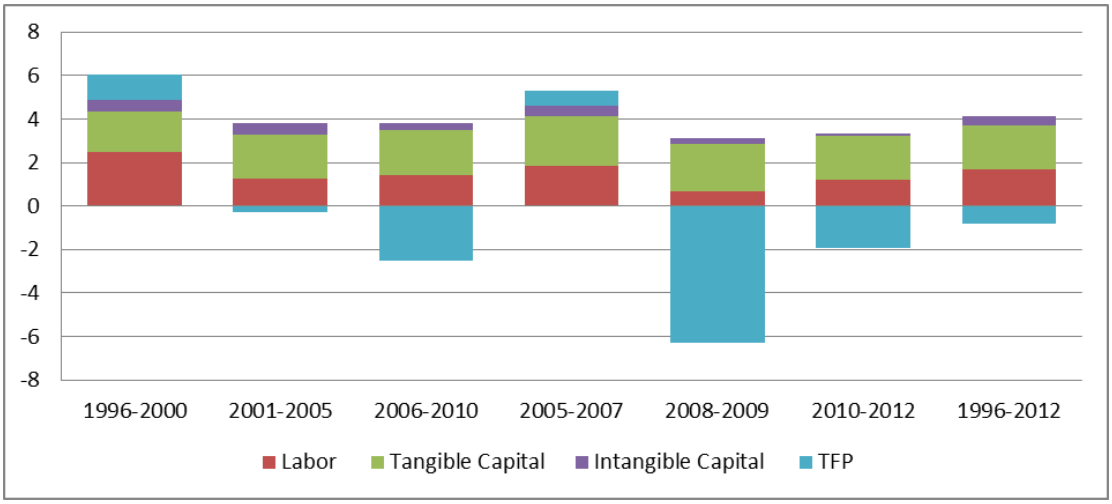
Graph. 8: Real Intangible Stock: CHS vs National Accounts (Million euros 2005 prices)



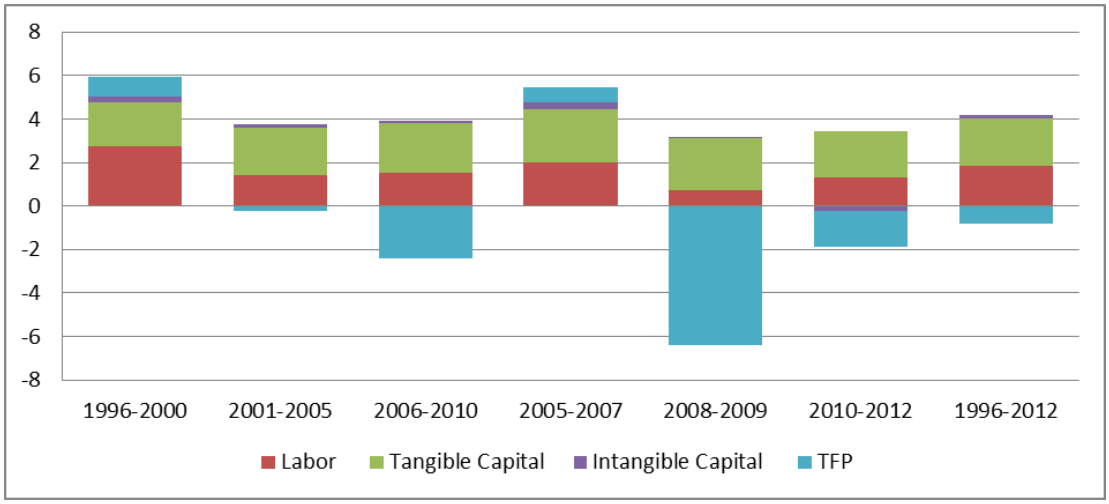
Graph. 9: GDP Growth Accounting Excluding All Intangibles



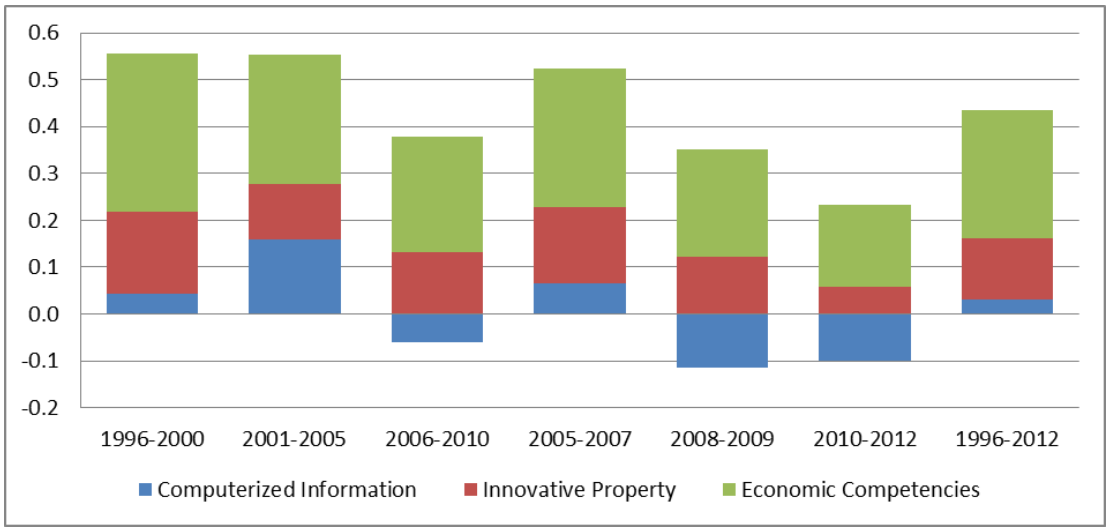
Graph. 10: GDP Growth Accounting Including All intangibles



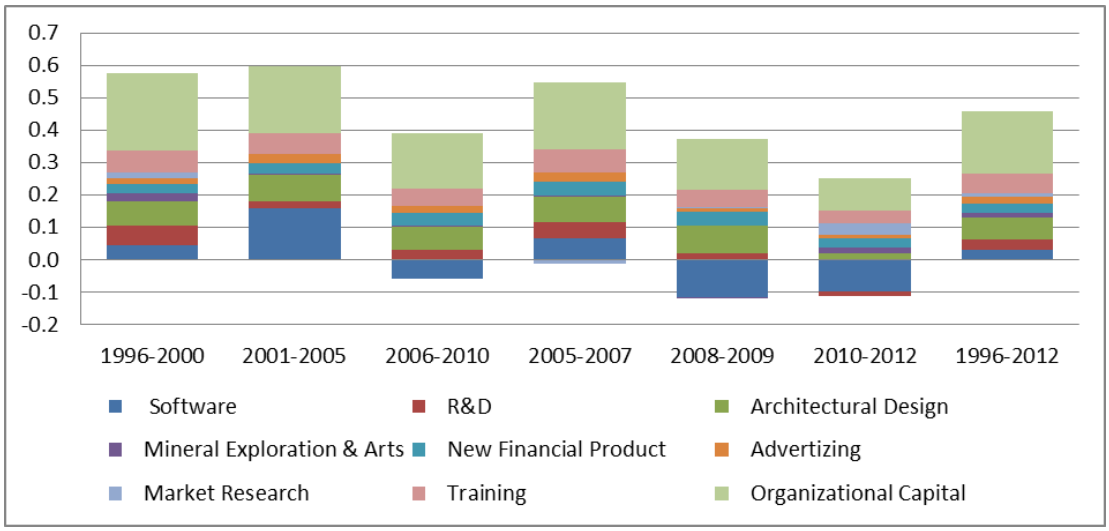
Graph. 11: GDP Growth Accounting With Intangibles Included in National Accounts



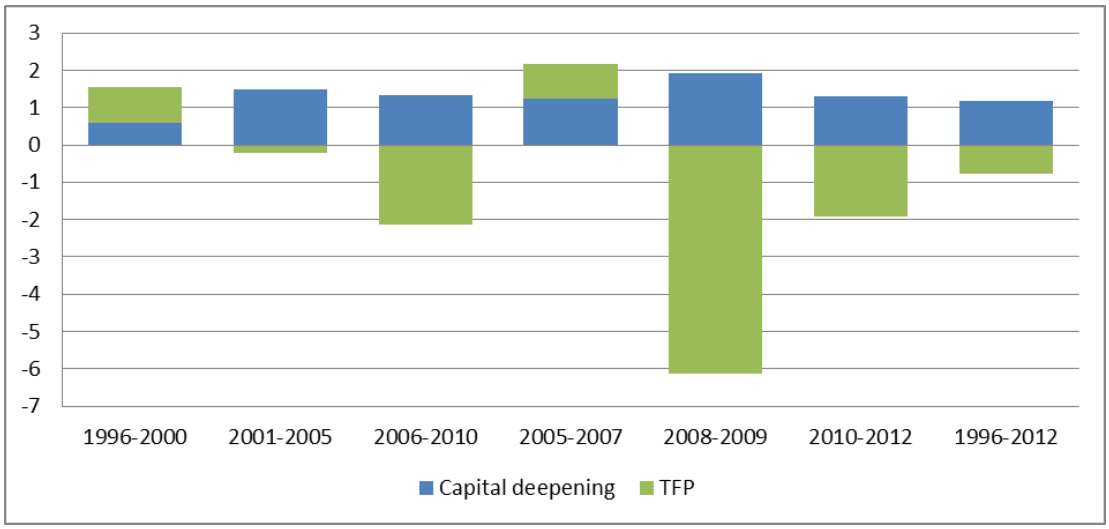
Graph. 12: Contribution of Intangible Capital to GDP Growth by CHS Category (percentage point)



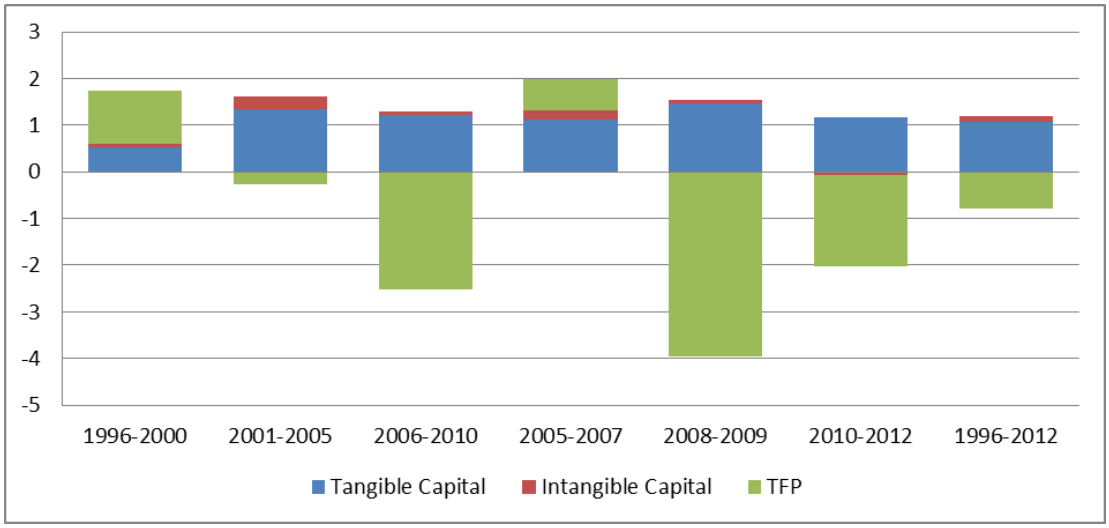
Graph. 13: Contribution of Each type of Intangible Capital to GDP Growth (percentage point)



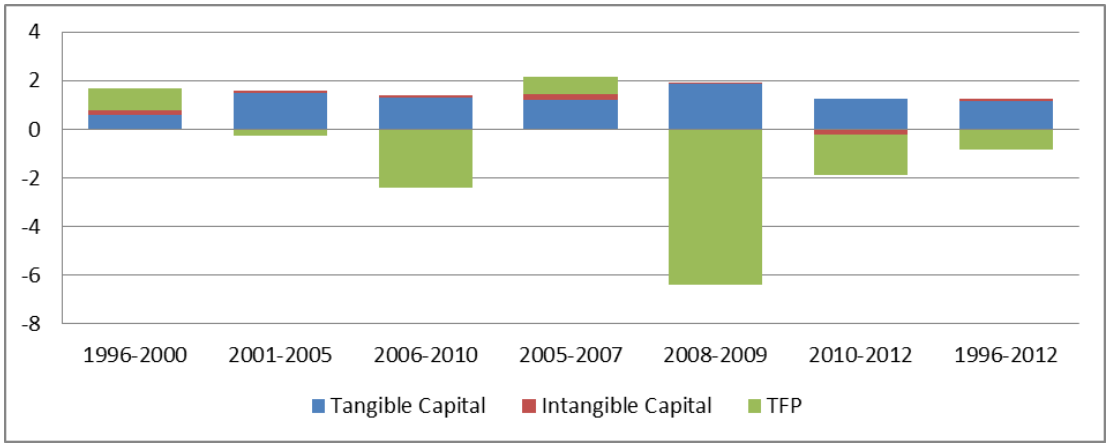
Graph. 14: LPG Growth Accounting Excluding All Intangibles



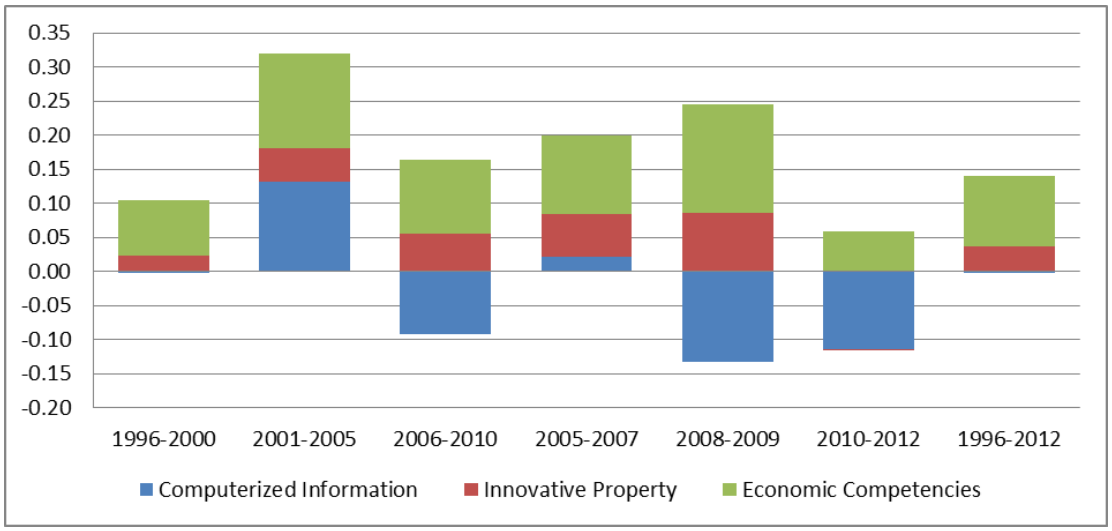
Graph. 15: LPG Growth Accounting Including All intangibles



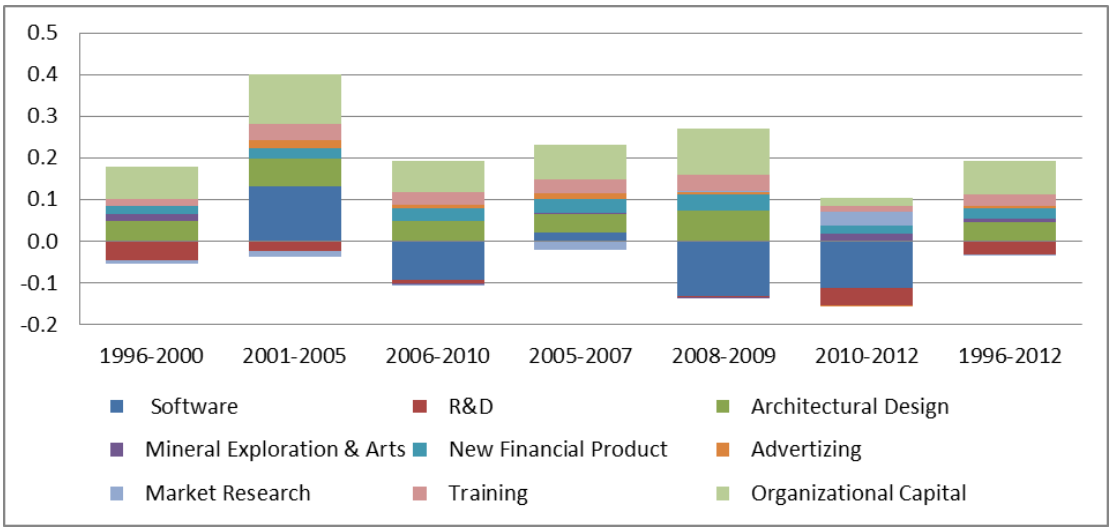
Graph. 16: LPG Growth Accounting With Intangibles Included in National Accounts



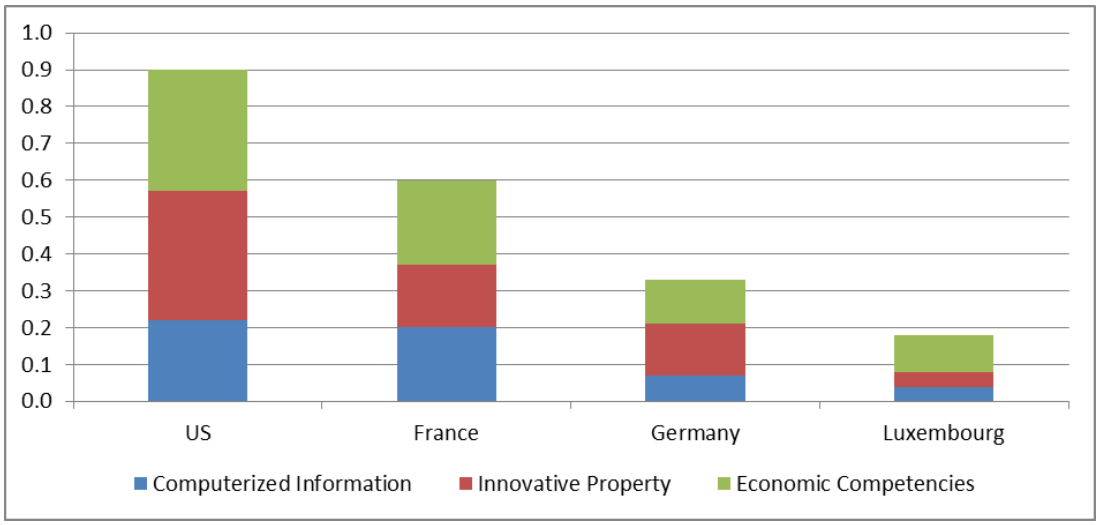
Graph. 17: Contribution of Intangible Capital to LPG by CHS Category (percentage point)



Graph. 18: Contribution of Each type of Intangible Capital to LPG (percentage point)



Graph. 19: Cross-Country Comparison of the Contributions of Intangible Capital to LPG by CHS Components 1995-2007



Appendix B: Additional tables

Tab. 1: Intangible to Tangible Investment Ratio and Annual Growth Rate of Intangible and Tangible Investment

	1995-2000	2001-2005	2006-2010	1995-2007	1995-2010
Ratio of Intangible to Tangible	0.66	0.70	0.72	**0.68**	**0.69**
Growth rate of Intangible (%)	7.26	2.57	1.35	**7.16**	**5.49**
Growth rate of tangible (%)	7.89	3.47	-2.17	**7.33**	**4.40**

Note: Data on tangible investments are extracted from INTAN invest databases.
Source: Author's calculation

Tab. 2: Intangible Assets Capitalized in Luxembourg Statistics

Asset type	Included in National Accounts
Computerized information	
1. Software	Yes
2. Databases	No
Innovative property	
3. Mineral exploration	Yes
4. R&D (scientific)	No
5. Entertainment and artistic originals	Yes
6. New product/systems in financial services	No
7. Design and other new product/systems	No
Economic competencies	
8. Brand equity	No
a. Advertising	No
b. Market research	No
9. Firm-specific resources	
a. Employer-provided training	No
b. Organizational structure	No

Source: Author

Tab. 3: Depreciation rates for Intangible Assets

Asset type	Depreciation Rate
Computerized information	
1. Software	0.315
2. Databases	0.315
Innovative property	
3. Mineral exploration	0.075
4. R&D (scientific)	0.15
5. Entertainment and artistic originals	0.2
6. New product/systems in financial services	0.2
7. Design and other new product/systems	0.2
Economic competencies	
8. Brand equity	
a. Advertising	0.55
b. Market research	0.55
9. Firm-specific resources	
a. Employer-provided training	0.4
b. Organizational structure	0.4

Source: Corrado et al. 2012

Tab. 4: Contributions of subcomponents of intangibles to Labor Productivity Growth, (1995-2007)

	Computerized Information		Innovative Property		Economic Competencies	
	Absolute	**Relative**	**Absolute**	**Relative**	**Absolute**	**Relative**
France	0.20	0.11	0.17	0.09	0.23	0.12
Germany	0.07	0.04	0.14	0.08	0.12	0.07
Luxembourg	0.04	0.03	0.04	0.03	0.1	0.07
Netherlands	0.17	0.07	0.12	0.05	0.22	0.10
US	0.22	0.08	0.35	0.13	0.33	0.12

Source: Corrado et al. 2012 and Author's calculation

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