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Intangible investment: Contribution to growth and innovation policy issues
A Franco-German comparison[1]

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1 Introduction

In the late 1960's first attempts to measure innovation in a national accounting framework have emerged. The 1968 System of National Accounts (United Nations (1968)) pointed out the possibility to include Research and Development in the GFCF account. Besides, human capital, education and health were also discussed as potential investment. However, conceptual issues and measurement problems were difficult to overcome in a national accounting framework. Software was the first intangible item to be included in the national accounts as investment in the 1993 version of SNA (United Nations (1993)).

The study and the measurement of intellectual capital and intangible investment has been considered from an analytical perspective by statistical offices in Europe in the 1980s and mid 1990s (Statistic Finland, 1987; INSEE, 1995; CBS, 1995) as well as from a more dynamic managerial perspective of innovation systems (Bounfour, 2003a, 2003b; Ståhle and Bounfour, 2008). It has been embodied in a formalised framework in the early 2000's with the work of Nakamura (2001) and Corrado, Hulten and Sichel (2005). Referring to them, the National Accounts do not value properly GDP, growth and productivity since a number of intangible assets are not accounted for as investment. Indeed, items such as R&D, training or advertising, amongst other, that are treated as intermediate consumption should be considered as investment since their effect in the production process is durable over time. The work from Corrado et al. (2005) estimates potential intangible investment in the US as much as 1 220 billion dollars annually between 1998 and 2000. Same type of measurement have been applied to other countries in recent years (Giorgio-Marano, Haskel & Wallis (2009), Fukao, Hamagata, Miyagawa & Tonogi (2007), Rooijen-Horsten, Bergen & Tanriseven (2008), Delbecque & Nayman (2010)). Intangible investment could amount between 15% and 23% of GDP in western European countries in 2006. This sizeable amount of unaccounted-for assets has been analysed in a Source Of Growth model in order to determine the effect of these "new" investment on productivity. Depending on the country, intangible investment could explain a large part of Total Factor Productivity.

However, most of these studies suffers two issues. First, the evaluation framework proposed by Corrado et al. (2005) lacks foundations in terms of both intangible assets definitions and measurement methods. Second, all studies focusing on the effect of including new intangible assets in the national accounts have only focused on the "direct" accounting effect of these assets.

In this study, the varieties of intangible assets are derived from Corrado et al. (2005) with several improvements implemented in Delbecque and Nayman (2010) and Delbecque (2011) in many aspects. First, definitions have been refined in order to focus on more precise intangible items. Second, the measure of intangible investment includes both the market and the non-market sector. Third, time series are updated to 2010 when possible. Finally, while previous studies use aggregate price indexes in order to deflate intangible investment, we calculate of real investment using appropriate disaggregated service price indexes.

Our contribution is threefold. First, based on intangible data for France, Germany, the UK, Sweden, Japan and the US, we assess the effect of intangible capital at the aggregate level but also in terms of asset combinations in order to identify asset complementarity. Second, whereas most empirical studies on intangible investment have assessed the "direct" accounting effect of including these investments in the GFCF account through growth accounting, we focus on the "indirect" effect of three production factors, namely, labour, tangible capital and intangible capital on output through the estimation of macro- production functions. Third, we specifically document intangible investment structure in France and Germany and within-country heterogeneity by focusing on the French industry structure and investment.

The paper is organised as follows. Section 1 sets the stage for the analytical work presenting factual data on intangible investment structures and trends in France and Germany. Section 2 formalises our theoretical framework. Section 3 briefly present the data. Empirical results are presented in Section 4. Section 5 extensively documents industry heterogeneity before concluding.

2 Facts and figures

France and Germany are at the centre of European Union creation and evolution, and have largely participated the orientation given to European economic development. Facing increasing competition from cost-competitive countries and the relocation of European industries in developing and transition economies, the Lisbon agenda has put the emphasise on the development of the so called "knowledge economy", innovation and higher-level education. However, innovation policies are multidimensional and optimal investments are difficult to establish as several questions arise when resource allocation is under heavy budget constraints. How should different production factors interact? Which type of innovation should be promoted? We will illustrate these questions with facts and figures.

Figure 1 shows tangible and intangible investment intensity relative to labour. Although France's intangible investment has been increasing faster than in Germany,

Figure 1: Tangible and intangible intensity

Source: Eurostat, Coinvest and authors' calculations.

the importance of innovation compared to tangible investment and labour has been decreasing between 2000 and 2010. The sharp rise in tangible investment during the same period shows that innovation in France is of second order within industrial strategy. Meanwhile, Germany's share of innovation within the whole production process has been increasing relative to labour and tangible investment. The first challenge for innovation policies thus concerns the mix between different production factors. These facts also show that innovation policies must be implemented accordingly to a global industrial and labour policy in order to optimise factors combinations.

Another set of questions relates to the type of innovations to be promoted. Amongst the list of intangible assets proposed by Corrado et al. (2005), are there any particular asset that is performance-driver? Again, we illustrate the variety of asset structure by comparing France and Germany (Figure 2).

Looking at the dynamics of innovation in France and Germany between 1995 and 2010 gives a first insight on differences that exist amongst main EU partners. The two countries show different, even opposite intangible investment structures and trends. Investment in software and database amounts to 20% of total intangible investment on an upward trend in France while it is valued 10% and stable in Germany. Conversely, investment in R&D is sharply decreasing in France, but increasing in Germany up to 28% of total intangible investment. Other items such as training or architecture and engineering design also exhibit different patterns. This clearly shows that investment strategies differ across countries. An evaluation of the performance of each asset could be highly informative in terms of innovation directions. This strictly descriptive analysis shows that inovation strategies are heterogeneous, even when comparing look-alike economies such as France and Germany. We now relate these strategies to performance and economic growth by focusing on the contribution of intangible assets on value-added.

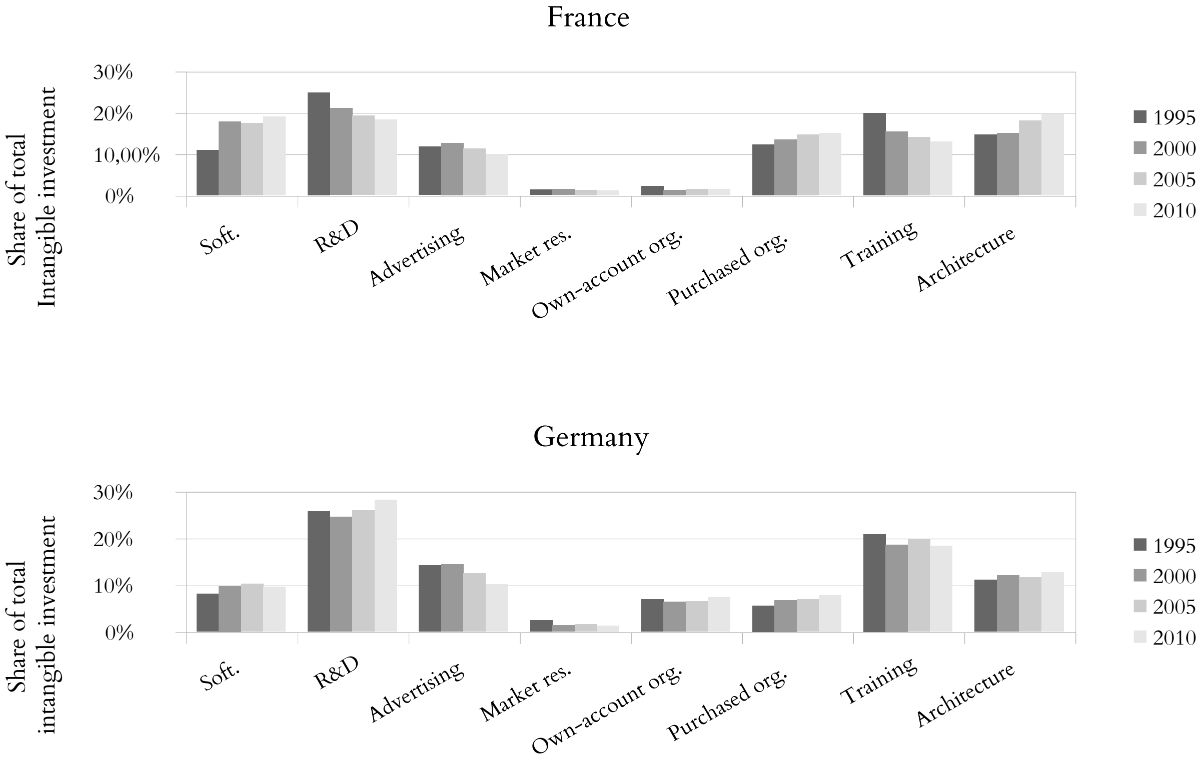
3 Economic model

We aim at measuring the contribution of new intangible assets on production. Beside traditional tangible capital and labour input we include new intangible capital as a production factor. The CHS framework is based on the national accounting point of view within which growth and productivity do not fully account for intangible inputs as assets. Consequently their approach concentrates on the accounting evaluation and measurement of the potential effect of including new assets in the calculation of GDP and productivity. This "direct" accounting effect of including or excluding new intangible investment in the GFCF account as been analysed for several countries (Corrado et al. (2005), Fukao et al. (2007), Giorgio-Marrano et al. (2009), Delbecque, Le Laidier, Mairesse, Nayman (2011)). Although we stick to the general framework proposed by CHS in terms of intangible items and a cost-based evaluation of these items, we focus on the "indirect" effect of intangible capital on value added. To that aim we estimate a macro production function using three inputs, namely, labour, tangible capital and intangible capital:

$$Y = F(K, L, I) \tag{1}$$

where Y is the value-added, L is the labour input, K is the tangible capital, and I the intangible capital.

Figure 2: Dynamic investment patterns in France and Germany



Source: Coinvest and authors' calculations.

We use a Cobb-Douglas production function including intangible capital as a third input:

$$Y = AL^{\alpha}K^{\beta}I^{\gamma} \quad (2)$$

Using the log-linear form of the production function:

$$logY = logA + \alpha logL + \beta logK + \gamma logI \quad (3)$$

where α, β and γ are parameters to be estimated. These estimations require the real values of value added, labour input, tangible and intangible capital stocks as prerequisite. Whereas value added, labour and tangible capital inputs values are provided by statistic offices, real intangible capital has to be calculated based on intangible investment estimations.

We calculate real intangible investment as the deflated value of current intangible investment using disaggregated service price indexes[1].

$$i_n = i_n^c \frac{1}{p_n} \quad (4)$$

with n denoting each intangible item, i_n^c the current value of intangible investment of item n and p_n the price index for item n.

Finally, we calculate the stock of each intangible asset using the perpetual inventory method as follows:

$$I_{n,t} = i_{n,t} + I_{n,t-1}(1 - \delta_n) \quad (5)$$

where δ_n is the annual depreciation rate of the stock item n.

4 Data

In order to evaluate the contribution of labour, tangible capital and intangible capital, we use different data sources to calculate real values of each input for six countries, namely, France, Germany, Sweden, the UK, Japan and the US.

4.1 Intangible investment

Intangible data used in this work are derived from the methodology proposed by CHS. Data for France are taken from Delbecque and Nayman (2010). They are originally collected for the 1980-2010 period and for both the market and the non-market sector.

[1]Most studies use the aggregate GDP price index in order to deflate intangible. However, service price have been increasing faster than the rest of the economy since the mid 1990's.

Intangible investment data for Germany, UK and Sweden are taken from COINVEST[2]. They are originally collected for the market sector only. In order to retrieve data for the whole economy, we estimate the non-market sector intangible investment based on the share of the non-market sector in related products' total consumption (these shares are derived from the use tables provided by EUROSTAT). As an example, non-market sector accounted for 11,6% of total R&D consumption in 2005 in the UK. We then assume the same share for the non-market R&D investment. Same methodology applies to other EU countries and all items.

In order to retrieve recent data up to 2010 we assume that the growth rate of each item corresponds to the growth rate of the corresponding product output. We apply these annual growth rates to the latest data available.

Table 1: Descriptive statistics
(million current Euros in 2005)

	Mean	*Max*	*Min*	*Std*
Software and database	47021	125553	6093	48263
R&D	61142	161674	6795	61909
Artistic originals	11747	44117	28	16765
Architecture and engineering design	49856	144026	3484	52965
Financial innovation	2543	6586	274	2748
Advertising and market research	35915	111557	2706	39404
Training	50336	180954	3316	65624
Organisation capital	40218	113965	4087	38904

Source: Coinvest and authors' calculations.

Data for US are derived from Corrado et al. (2005). These data are originally estimated on a five-year average basis up to 2006 for the market sector only. We calculate data on an annual basis using related sectors growth obtained from the input/output tables from the BEA. US data are retrieved for the 1980-2009 period. Non-market sector estimations for the US are based on the Input/Output tables from the BEA.

Data for Japan are provided by Fukao et al. (2009). They are originally estimated for the whole economy, including non-market sector. We extend the data coverage up to 2009 applying annual growth of related-product to each item.

Table 1 displays descriptive statistics for these data. R&D, training, architecture and engineering design are the most important items in terms of amount of investment. Financial innovation and artistic originals are less important on average.

4.2 Intangible capital

While most studies use aggregate value-added prices as deflators for intangible investment, we use specific service prices indexes in order to calculate real values for intangibles. Indeed, value-added prices are not appropriate since service prices have grown at a fastest pace than the rest of the economy since the late 1990's[3].

Starting from real intangible investment, as presented in Section 2, we calculate real intangible capital stocks using perpetual inventory method for each intangible item using current or assumed depreciation rates (Appendix A).

4.3 Tangible investment

Tangible investment data are provided by Eurostat for all EU countries, Japan and the US. These data include both the market and the non-market sector, and are available up to 2009 and for 2010 as forecast. Tangible investment data are given in both nominal and real terms.

4.4 Tangible capital

We rely on the data provided by EUKLEMS[4] for the industry-level analysis at the NACE-17 level (rev. 1). Tangible capital data are available up to 2007. We estimate capital stocks for years after 2007 using EUKLEMS weighted average depreciation rates across tangible items and industries.

4.5 Labour

The labour input data are taken from the Annual Labour Force Statistics (ALFS) from the OECD. We use the annual average number of employees in full time equivalent as the labour production factor.

5 Estimations

We assume that production patterns are modelised as a Cobb-Douglas production function (see Section 2). Using Eq. 3 as a starting point, we estimate an aggregate production function on panel data.

Panel data analysis are useful when dealing with multidimensional data, namely, cross-country and time-series. This analytical tool allows to account for

[2]http://www.coinvest.org.uk/bin/view/CoInvest
[3]Please refer to Delbecque (2011) for more details.
[4]http://www.euklems.net/

both durable subject-specific effects and common time shocks. In our case, the productivity parameter can have different values across countries due to local unobservable characteristics, besides, recessions may impact all countries at the same time. If not properly treated, these effects could be included in the error term leading to biased estimates. The methodology allows for both subject-specific parameter et time effects through the use of individual- and time-effects.

The estimated equation can be written as follows:

$$logY_{it} = \alpha_i + \beta_1 logL_{it} + \beta_2 logK_{it} + \beta_3 logI_{it} + \phi_t + \epsilon_{it} \quad (6)$$

where i denotes the country and t the time period. α_i is a subject-specific parameter, ϕ_t is the time specific parameter and ϵ is an error terms with zero mean and constant variance.

In order to estimate panel data on balanced sample we restrict the time period to 1995-2009. Column (A) displays the contributions of labour and tangible capital to total value added. The contribution of labour to aggregate VA is more than four times higher than the contribution of tangible capital during the 1995-2009 time period. The log-log form of the production function allows us to interpret coefficients in terms of elasticities. A 10% increase in labour input would increase GDP by almost 20%. Besides, a 10% increase in tangible capital would increase GDP by 4.2%.

We then include intangible capital in the estimation. Before commenting the results, let us formulate a short remark on the endogenous variable. In estimation including intangible capital, value-added is calculated as the real GDP taken from Eurostat added with the real value of intangible investment. Indeed, considering some intangible items as investment rather than intermediate consumption has a direct effect on the level of GDP. In order to account for this potential investment, we add these new items in the valuation of GDP.

We find that the contribution of intangible capital on GDP is lower than those of labour and tangible capital (column B), the relative impact of tangible compared to intangible capital is two times higher. A 10% increase in intangible capital would raise GDP by 1.8% (compared to 3.9% for tangible capital). Note that marginal effects of labour and tangible capital are not comparable between column (A) and (B) since the endogenous variable is not the same in both estimation.

Finally we compare two types of intangible capital. In one hand, capital that is already considered as an asset in the national accounts (software, architecture, and artistic originals) and on the other hand "new" intangible items (organisation, advertising, market research, training, financial innovation) (Table 2, column C). We find that the potential effect of "new" intangible capital is strong and highly significant compared to "old" intangibles and tangible capital.

Table 2: Baseline specification with two-way fixed-effects

	A	B	C
$logL$	1.97***	1.32***	1.14***
	[0.18]	[0.15]	[0.13]
$logK$	0.42***	0.39***	0.18**
	[0.12]	[0.07]	[0.09]
$logI$		0.18**	
		[0.05]	
$logI_{GFCF}$			0.01
			[0.04]
$logI_{non-GFCF}$			0.36***
			[0.09]
R-sq	0.99	0.99	0.99

***, ** and * denoting estimators significant at 1%, 5% and 10% level respectively.

Source: Authors' calculations.

This is a first insight of heterogeneity amongst intangible items and the difficulty to evaluate their effect as a whole. We thus turn to a disaggregated analysis of this production function.

Table 3 displays estimation results when including software, R&D, advertising and organisation capital sequentially (column A to D) and all together (column E).

Table 3: Item by item estimations

	A	B	C	D	E
$logL$	1.45***	1.70***	1.76***	1.41***	0.91***
	[0.14]	[0.16]	[0.15]	[0.18]	[0.22]
$logK$	0.48***	0.39***	0.35***	0.48***	0.65***
	[0.09]	[0.1]	[0.1]	[0.11]	[0.11]
$log(Soft)$	0.16***				0.24***
	[0.03]				[0.05]
$log(R\&D)$		0.05			0.13***
		[0.04]			[0.05]
$log(Adv)$			0.11**		-0.06
			[0.04]		[0.05]
$log(Org)$				0.10***	0.15***
				[0.04]	[0.04]
R-sq	0.99	0.99	0.99	0.99	0.99

***, ** and * denoting estimators significant at 1%, 5% and 10% level respectively.

Source: Authors' calculations.

First, we find, in all regressions that the contribution of labour is always stronger than the contribution of tangible capital or intangible items.

Intangible items taken independently show positive contribution to value-added except R&D (column B) that is estimated non-significant. Finally, when including the four items together software and organisation capital have the strongest impacts amongst intangibles. However, given the high degree of correlation between intangible assets, we may face collinearity issues leading to biased coefficient estimates (see correlation table in appendix C).

Analysing intangibles separately is convenient for determining each potential effect on production and growth. However, there is little rationale for assuming strict independence between them. Indeed, it is probable that combinations of intangibles and various investment patterns could lead to different outcomes. Moreover, determining optimal groups of investments is crucial for public decisions in terms of innovation policy orientation. We thus focus on groups of intangibles rather than assessing them individually or fully aggregated.

Table 4: Intangible assets combinations

	A	B	C
$logL$	1.32***	0.68***	1.36***
	[0.15]	[0.2]	[0.15]
$logK$	0.39***	0.50***	0.30***
	[0.07]	[0.11]	[0.1]
$logI$	0.18**	0.09*	
	[0.05]	[0.05]	
Overall innov. index		0.03***	
		[0.01]	
Training (+) vs Org (-)		-0.01	
		[0.01]	
Org-Training (+) vs Soft-R&D (-)		0.01	
		[0.01]	
$logI_{proc}$			0.39***
			[0.1]
$logI_{prod}$			-0.12*
			[0.07]
Rsq	0.99	0.99	0.99

***, ** and * denoting estimators significant at 1%, 5% and 10% level respectively.

Source: Authors' calculations.

We first use innovation indexes obtained from a principal component analysis based on all intangible investment items (see appendix B for details). The first three components contribute to more than 90% of total dispersion of the data. The first index is an overall innovation index where all items contribute positively. The second index opposes training (positive effect in the index) to organisation (negative effect). The third index opposes organisation and training (with positive signs) to software and R&D (with negative signs).

We only find significant positive effect with the overall innovation index. The other two indexes having non-significant coefficients (Table 4, column B). The magnitude of the effect is not directly interpretable since the index is a composite of several items.

These combinations of items are not performance drivers in our analysis. We thus focus on an other form of asset bundle. We assume two types of intangible capital, namely, process innovation and product innovation. The former includes all investments related to the development of new products (R&D, advertising, market research, architecture and design), the later is made of innovations related to the improvement of production processes (training, organisation capital, software and databases). Results are given in Table 4 column C. We find a significantly strong positive effect of process innovation on value-added compared to a barely significant low negative effect of product innovations. A 10% increase in process innovation capital could lead to close to 4% increase in value added. This sizeable effect is even stronger than the contribution of tangible capital.

This result is of particular interest for developed countries. Indeed, international competition on goods markets based on cost constraints has increased the incentive for these countries to differentiate their product by emphasising new product development. But our results show that performance does not come from product innovation, rather from process innovation. Competition would take place on the way of producing goods rather than on the goods themselves.

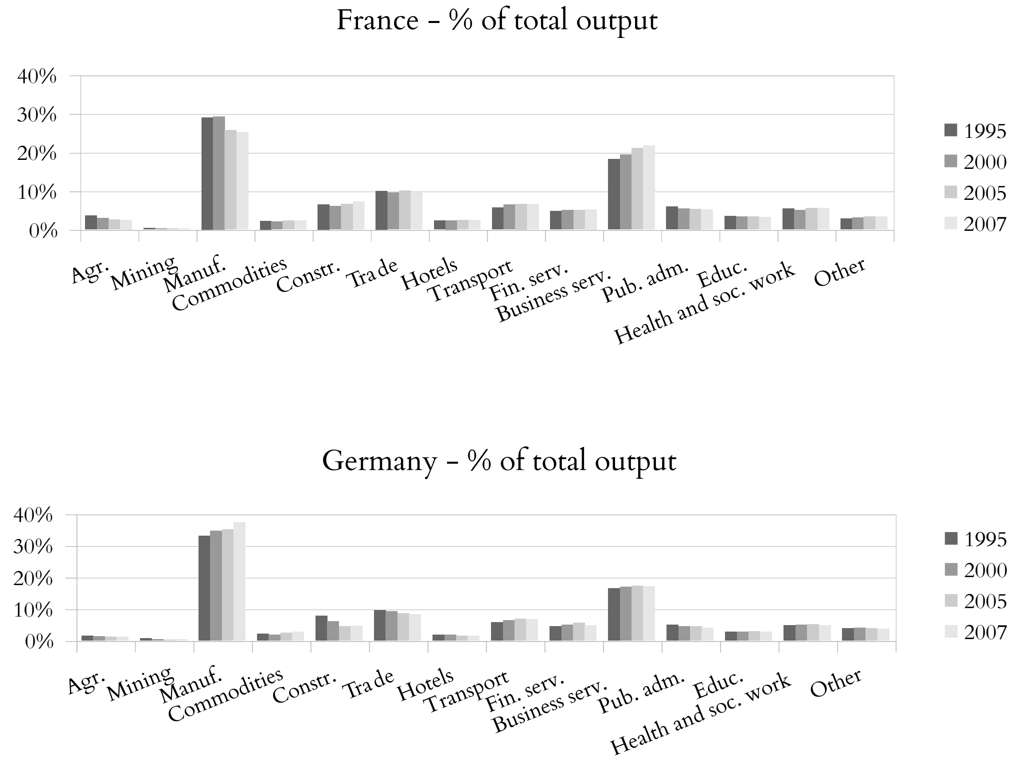
Results presented in this section yield mixed conclusions. First, intangible capital as a whole does have a significantly positive impact on GDP. Still, at the aggregate level, it contributes less to GDP growth than tangible capital or labour. Second, when assessing the effect of disaggregated main intangible items, we also find positive effects of software, advertising and organisation while R&D seems not to play a significant role in increasing value-added. When including the main intangibles altogether in the regression, results show strongest impact of software and organisation capital, though the interpretation is sensitive due to the presence of collinearity between assets. Finally, when looking at assets combinations, the previous result is confirmed. We find a strong positive effect of process innovation (including organisation capital and software) compared to product innovation (including R&D and advertising).

Assessing more detailed assets combinations and complementarity is delicate at such a level of aggregation due to both between- and within-country industry heterogeneity. We will focus on these issues in the following section.

6 Extended heterogeneity analysis

The macro analysis presented in the previous sections gives a general view of intangibles and their impact

Figure 3: Industry distribution in France an Germany

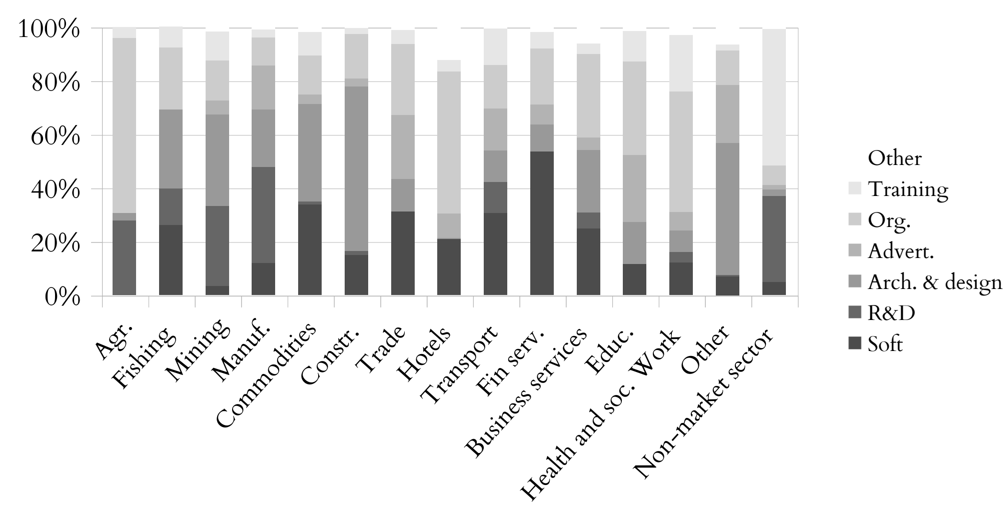


Source: Authors' calculations.

on aggregate value-added. However, heterogeneous industry-structures may yield some issues in determining optimal investment strategies. In this section we specifically focus on industry composition in France and Germany and investment patterns at the industry-level in France.

Just as investment schemes are different from a country to another (Figure 2), so are industry structures. Figure 3 show three striking differences between France and Germany in terms of industry development. From 1995 to 2007, the share of the manufacturing industry in total output has been decreasing from 30% down to 25% in

Figure 4: Intangible items distribution by industry in France in 2007 (NACE 17)



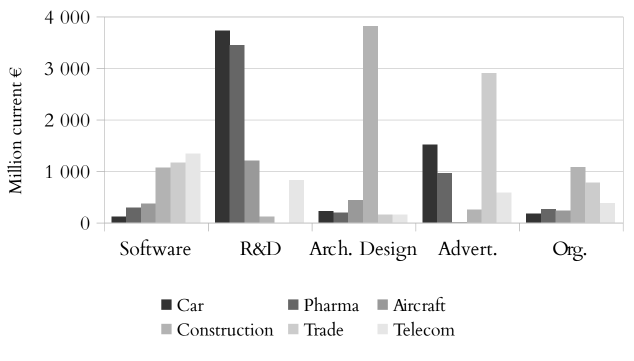
Source: Authors' calculations.

France while increasing up to 37% in Germany. Meanwhile, the business service industry grew 4 percentage points up to 22% in France but remained steady in Germany at 17%. Smaller differences also appear in the construction industry or in the wholesale and retail trade industry. These dynamics shed some light on innovation structures and trends displayed in Figure 2. The manufacturing industry invests massively in R&D compared to other industries and the service industry is highly intensive in computer software and databases (Figure 4). These industry's features partly explain trends in intangible investment. R&D investment in Germany has been increasing jointly with the development of the manufacturing industry.

Looking in detail at the industry-level structure of innovation in France, again, shows high heterogeneity in investment decisions at a disaggregated level (Figure 4). Agriculture, mining and manufacturing invest intensively in architecture, design and R&D compared to other industries. Conversely, service industries (transport, trade, business services, financial services, etc...) invest massively in software, database and organisation capital.

Heterogeneity is even more sizeable at a very detail level of disaggregation (French NES 118-industries[5]). Figure 5 displays investment in main intangible items by major French industries, namely, car, pharmaceutical, aircraft, construction, trade and telecommunication. Each of these industries investing in a specific item. The car and pharmaceutical industries are major contributors to R&D investment, while the construction industry is intensive in architecture and design, and wholesale and retail trade invest most in advertising. Software and organisation are somehow less industry-specific, but still more important in the service industries.

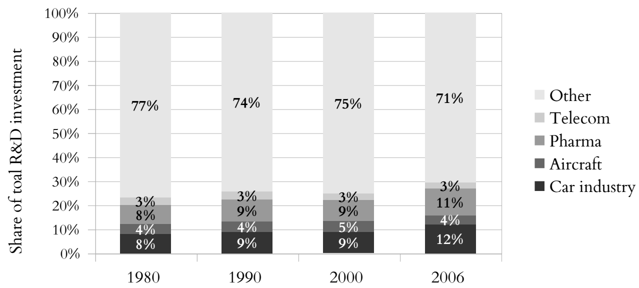
Figure 5: Industry heterogeneity – Main intangible items in major industries in 2007



Source: Authors' calculations.

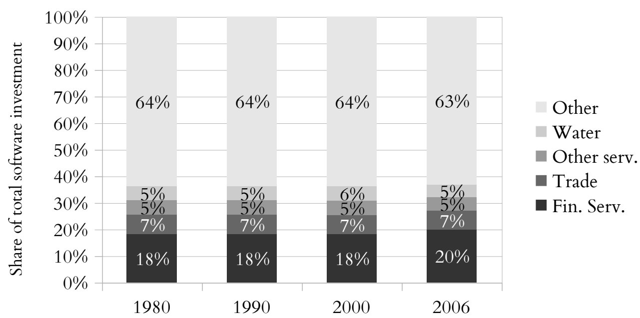
Another source of heterogeneity comes from the differences in industries and investment sizes. A few industries account for a large part of intangible investment. As an example, amongst 118 French industries, four of them account for 30% of total R&D investment (Figure 6). This feature could be an incentive to implement innovation policies towards easily identified core industries made of a very few firms. Implementing innovation policies towards the remaining 114 industries is much more challenging since it is made of heterogeneous "small" economic agents, though accounting for 70% of R&D investment. Same concentration appears for investment in software (Figure 7). Financial services, and wholesale and retail trade account for one fourth of total software investment.

Figure 6: Industry heterogeneity – concentration of R&D investment



Source: Authors' calculations.

Figure 7: Industry heterogeneity – concentration of Software investment



Source: Authors' calculations.

Finally, the non-market sector can be a key player in innovation dynamics. Intangible investment by the non-market sector is valued more than 20% of total intangible investment in France (Delbecque and Nayman (2010)). These characteristics have to be taken into account properly. The two main innovation items for public institutions are R&D, which is embodied in universities and public research centres, and training[6]. As

[5]http://www.insee.fr/fr/methodes/default.asp?page=nomenclatures/nes2003/nes2003.htm
[6] Note that these figures do not include initial training and education spending.

public administration do not produce much recorded or valued services or good, an input/output analysis is not suitable for the non-market sector. Consequently, the effect of non-market sector innovation has to be assessed in terms of externalities. Although these externalities are indirectly accounted for in the macro analysis presented in this work, they are to be precisely addressed and modelled in an industry-level input/output exercise. As an extension, the analysis of inter-industry externalities through supply and use of intermediate consumption has to be taken into account.

7 Conclusion

Using recent and updated data, we estimate the contributions of labour, tangible and intangible capital on growth through the estimation of production functions. These contributions are estimated using panel data analysis on six countries over 15 years. We first find that intangible capital, including software, R&D, architecture and design, advertising, training and organisation, contribute positively to growth as a whole, though this contribution is lower than the contribution of labour and tangible capital. Second, when disaggregating intangible items, we also find positive effects of main items, especially software and organisation. Finally, we assume particular forms of intangible assets combination, namely, product innovation and process innovation. While the former has very small impact on growth, the later contributes highly to economic performance.

A more detailed analysis shows very heterogeneous intangible investment patterns in several directions. First, manufacturing industries invest most in R&D, architecture and engineering design while service industries are intensive in software and organisation. Second, when looking at a more disaggregated industry-level, we find that investment is even more industry-specific. Finally, innovation, and particularly R&D is highly concentrated within a very few large industries, such as cars, pharmaceutical, aircraft and telecommunication.

These results yield several conclusions in terms of innovation policies. First innovation incentives are to be promoted since they effectively contribute to growth. However, they must not be implemented at the expense of labour and industrial policies since labour and tangible capital are still the main drivers of economic growth. Second, more incentive should be put on process innovation since they are highly performing compared to product innovations. Although European countries have active policies in therms of R&D investment, the improvement of production processes are left to private agents who may not focus on general benefit. The implication of public decisions on process improvements could be more profitable since it would also encompass potential externalities on employment. Third, innovation policies need to be industry-specific. All types of innovations do not apply to all industries. Appropriate incentives should be determined in order to be efficient at the industry level rather than being implemented at the macro level.

All these results illustrate the need for a more disaggregated input/output analysis at the industry-level. It would better account for differences in innovation needs, in sizes, in overall growth contribution. Moreover, an extended analysis of externalities would be highly informative since connexions between industries yield implicit innovation transfers. This is specifically the case of non-market sector innovation which has eventually direct or indirect effects on other sectors performance but cannot be accounted for in a strict input/output framework.

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A Depreciation rates for intangible assets

Table 5: Depreciation rates for intangible assets

	Depr. rate
Software and database	0,32
Artistic originals	0,2
Architecture and engineering design	0,2
Mineral exploration	0,2
R&D	0,2
Advertising and market research	0,6
Organisation capital	0,4
Financial innovation	0,2
Training	0,4

Source : Giorgio-Marrano, Haskel et Wallis (2009).

B Principal component analysis

We run a Principal Component Analysis (PCA thereafter) on all intangible items in order to categorise them and build aggregate innovation indicators reflecting actual asset bundle. In order to get rid of time correlation and within-country correlation, we use eigenvalues of the partial correlation matrix in order to determine the number of principal component to use.

We find that the three first component account for more than 90% of data total dispersion. We thus retain these component as innovation indexes to be used in the regression.

All variables have a positive sign in the first component with the training variable having less weight than the other variables. This indicator is an overall innovation indicator. The higher the value of each item, the higher the value of the indicator.

Table 6: Eigenvalues of the Partial Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulated
1	3.14990901	1.60401687	0.525	0.525
2	1.54589214	0.61357108	0.2576	0.7826
3	0.93232106	0.75136594	0.1554	0.938
4	0.18095512	0.07294858	0.0302	0.9682
5	0.10800654	0.0250904	0.018	0.9862
6	0.08291614		0.0138	1

Source: Authors' calculations.

In the second component, three variable are overweighted, architecture and engineering design, training and organisation. The former having positive sign contrary to the later. The higher the investment in organisation, the smaller the index. Conversely, the higher the investment in training, the higher the index.

Finally, the third component opposes software and R&D with negative signs to training and organisation with positive signs.

Please refer to Delbecque (2011) for more details on the results of the PCA.

Table 7: Eigenvectors

	1^{st} PC	2^{nd} PC	3^{rd} PC	4^{th} PC	5^{th} PC	6^{th} PC
Software	0.513809	−0.160726	−0.243217	0.207315	0.776944	−0.066264
R&D	0.46847	0.024126	−0.513608	0.350021	−0.530415	0.335121
Advertising & Market research	0.50946	−0.105767	0.346576	0.031269	−0.319327	−0.711478
Architecture and design	0.396276	0.506428	−0.076072	−0.751131	0.029969	0.124954
Training	0.118292	0.657634	0.505818	0.493437	0.102326	0.209096
Organisation capital	0.293187	−0.522921	0.543413	−0.160781	−0.040976	0.563709

Source: Authors' calculations.

C Intangible assets correlation

Table 8: Pearson partial correlations and associated probabilities of rejecting H0

	Soft	R&D	Advert.	Training	Org. cap.	Artist	Arch	Fin innov
Soft	1,00000	0,55340	0,53854	−0,69613	0,52177	−0,28319	−0,20187	0,50569
		<,0001	<,0001	<,0001	<,0001	0,0086	0,0639	<,0001
R&D	0,55340	1,00000	−0,19191	−0,84872	−0,12437	−0,69652	−0,74219	0,59395
	<,0001		0,0785	<,0001	0,2568	<,0001	<,0001	<,0001
Advert.	0,53854	−0,19191	1,00000	0,06494	0,77997	0,36189	0,37867	0,03691
	<,0001	0,0785		0,5549	<,0001	0,0007	0,0004	0,7373
Training	−0,69613	−0,84872	0,06494	1,00000	−0,04599	0,67306	0,62747	−0,64781
	<,0001	<,0001	0,5549		0,6760	<,0001	<,0001	<,0001
Org. cap.	0,52177	−0,12437	0,77997	−0,04599	1,00000	0,56549	0,29542	0,41642
	<,0001	0,2568	<,0001	0,6760		<,0001	0,0061	<,0001
Artist.	−0,28319	−0,69652	0,36189	0,67306	0,56549	1,00000	0,67007	−0,01510
	0,0086	<,0001	0,0007	<,0001	<,0001		<,0001	0,8909
Arch.	−0,20187	−0,74219	0,37867	0,62747	0,29542	0,67007	1,00000	−0,38498
	0,0639	<,0001	0,0004	<,0001	0,0061	<,0001		0,0003
Fin. Innov.	0,50569	0,59395	0,03691	−0,64781	0,41642	−0,01510	−0,38498	1,00000
	<,0001	<,0001	0,7373	<,0001	<,0001	0,8909	0,0003	

Source: Authors' calculations.