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Intangible capital and value creation: A comparative industry analysis

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ABSTRACT

This paper investigates the effect of intangible assets on value creation for sixteen French industries from 1980 to 2007. This work is based on original intangible investment data build from the French national accounts and encompassing a wide variety of assets. Our research yields several results. First, data analysis shows that, despite common thought, manufacturing industries are more intangible intensive than service industries. Second, by estimating aggregate and industry-level production functions, we find that the contribution of intangible assets are highly heterogeneous across industries. While the car industry, consumption good industry and financial services use these assets efficiently, the picture is less clear for other industries.

The productivity slowdown experienced by developed economies during the 1990's has been challenging for both economists and national accountants. While all industries started to extensively integrate computing and software into their production processes, economic performance and related productivity did not match expectations. One potential reason proposed by Nakamura (2003) was that the measurement of the economy was not accounting for all forms of capital and more precisely, intangible capital. R&D capital has long been considered as an asset (rather than an expense) by economists. In national accounting manuals however, R&D only appeared as an investment in the 2008 version of the System of National Accounts (SNA) (United Nations (2008)). This gap between accounting references and applied research has widened when Corrado, Hulten and Sichel (2005) (CHS, thereafter) proposed a list of intangible items that could be considered as assets due to their lifespan and their ability to remain in the production process. While the national accounts include software, database, artistic originals, and mineral exploration in the Gross Fixed Capital Formation account (GFCF), the authors propose to extend this list to R&D, advertising, organisation capital, continuous training and financial innovation.

Estimations of potential intangible capital have been implemented in several countries such as the US (CHS (2005, 2009), the UK (Giorgio-Marrano et al. (2009)), Japan (Fukao et al. (2009)), the Netherlands (Rooijen-Horsten et al. (2008)), France (Delbecque & Nayman (2010)), Sweden (Edquist (2009)). Referring to these studies, intangible investment could amount up to 11% of GDP and its effect on productivity and growth, although highly heterogeneous across countries, is far from negligible.

Macro estimations and analyses are interesting in comparing structures and performance across countries. However, heterogeneity arising within countries (i.e. across industries) is challenging and requires attention in order to properly assess intangible assets efficiency as well as appropriate innovation policy tools (Delbecque & Bounfour (2011)). Indeed, while innovation goals are set at the national level or supra-national level (the Lisbon agenda applies to all EU countries), industry specificities may require more disaggregate evaluation and policy tools. Industries differ not only in production processes but also in inputs requirement. In addition, given the multiple forms of innovation, the detailed analysis of distinct intangible assets as well as asset combination has to be addressed (Laranja et al. (2008)).

Industry level analysis raises three questions. First, what are industries' investment and innovation patterns, and how do they differ between industries? Second, how does intangible capital contributes to values creation? Third, what are the implications in terms of innovation policy?

Indeed, although innovation could arise in all industries, it might take heterogeneous forms and should be clearly identified. Moreover, such analytical work needs reliable intangible capital data at the industry level. To our knowledge, industry-level analyses have hardly been launched, except by Crass et al. (2010) and Edquist (2011).

We contribute to the empirical literature by implementing an industry-level analysis on French data. Based on French national statistics data, we estimate intangible investment for 118 industries, including public administrations. Using homogeneous data allows for reliable and comparable information across industries and items. We then assess the contribution of intangible capital alongside with tangible capital and labour on manufacturing and service industries separately as well as on individual industries.

The paper is organised as follows. Section 1 presents the methodology and the data sources. Section 2 details investment data features. Section 3 implements an advanced statistical analysis of assets combination. The contribution of input factors to value creation is analysed in section 4 before concluding.

1 Methodology and data sources

1.1 Production function estimation

The need for implementing efficient innovation policies implies that innovation tools are clearly identified and that their contribution to value creation has been assessed. We focus on this particular goal by applying new intangible asset data to a industry-level Cobb-Douglas production functions. Moreover, as we might suspect different patterns and contributions of innovation across industries, accounting for industry heterogeneity is of prime interest. So far, innovation policies have mainly been focusing on R&D as the main innovation driver , excluding de facto other type of innovation more related to processes than products (Moncada-Paternò-Castello et al., 2010, Delbecque & Bounfour (2011)). Moreover, not accounting for industries specificities would lead to inappropriate, even, counterproductive policies.

In the CHS framework, we assume that value-added (Y) results from a combination of not only labour (L) and tangible capital (K) but also intangible capital (I):

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

We implement a three-factor Cobb-Douglas production function in order to characterise production patterns[1]:

$$Y = AL^{\alpha}K^{\beta}I^{\gamma} \tag{2}$$

Using the log-linear form of the production function:

$$logY = logA + \alpha logL + \beta logK + \gamma logI \tag{3}$$

where α, β and γ are parameters to be estimated.

1.2 Intangible investment

Relying on the Corrado, Hulten & Sichel (2005) measurement framework, and following Delbecque & Nayman (2010) and Delbecque & Bounfour (2011), we build industry-level intangible data based on the French input/output table from the INSEE (Institut National de la Statistique et des Etudes Economiques). The INSEE provides input/output tables for 118 crossed industries and products between 1999 and 2008[2]. This provides us with very detailed data on both the types of products (or assets) acquired and the distribution of acquisition by industry. Prior to 1999, data are available at a 36-industry level.

The CHS framework identifies 13 intangible items that could be capitalised, including software, database, advertising, R&D, artistic originals, architecture and engineering design, mineral exploration, advertising, market research, organisation capital (acquired and internally produced), financial innovation and continuous training. In the French NES 118 classification, 10 of these items are individually measured either as investment or as spending (Table 1).

The measurement of the remaining items relies on labour or tax data. More precisely, in the French national accounts, software, artistic originals, architecture, engineering design and mineral exploration are already recorded as investment. We thus use these data without any modification.

Continuous training is estimated using firms' tax forms covering spending in training. Firms can choose between providing training directly to their employees or pay a "training tax" in order to fund indirect training provided by training centres. The fiscal administration thus asks firms to declare the amount spent on training in a specific tax form.

Internally produced advertising and organisation capital, and financial innovation are estimated using labour surveys (Enquête Emplois and Enquête Emplois en Continu) provided by the INSEE. These surveys describe, amongst other, employment and wages at the NACE 4-digit level detailing 412 occupations in the French PCS occupation classifications[3].

The baseline assumption made in the CHS framework is the following. A number of intangible items are considered as intermediate consumption despite their capacity to remain in the production process longer than a year, just as assets do. As a consequence, spending in these items should be considered as investment rather than consumption.

Intangible investment is estimated in a two-step process. First, for each item proposed by CHS, and following Delbecque & Nayman (2010), we estimate the share of each item's consumption that could be capitalised. Second, in order to disaggregate investment at the industry level, we estimate the share of each industry in total consumption and apply the same share to investment. The 118-industry disaggregation level is available from 1999 to 2008. We estimate data back to 1980 assuming constant share of 118-level industries in upper categories (36 categories). Same methodology applies for years 2009 and 2010.

[1] Note that we do not assume any restriction on returns to scale.

[2] Industries and products are identified using the French NES classification. The French input/output tables used to build intangible investment data here are no longer available on the statistics office website since the change in reference year in 2011. New I/O data are not publicly available at such a detailed level.

[3] http://www.insee.fr/fr/methodes/default.asp?page=nomenclatures/pcsese/pcsese2003/pcsese2003.htm

Table 1: Intangible data sources and assumptions

Item	*Data source*	*Assumed share of investment in total spending*	*Depreciation rate of asset*	*Already in the French GFCF account*
Software (produced and purchased)	GFCF account	-	0,32	yes
Database	I/O tables	100.00%	0,32	no
Artistic originals	GFCF account	-	0,2	yes
Architecture and engineering design	GFCF account	-	0,2	yes
Mineral exploration	GFCF account	-	0,2	yes
R&D	I/O tables	100.00%	0,2	no
Advertising (purchased)	I/O tables	80.00%	0,6	no
Advertising (produced)	Enquête Emploi (labour survey)	50% of total cost	0,6	no
Market research	I/O tables	100.00%	0,6	no
Organisation capital (purchased)	I/O tables	50.00%	0,4	no
Organisation capital (produced)	Enquête Emploi (labour survey)	20% of total cost	0,4	no
Continuous training	Training tax forms	90% of total training cost declared	0,4	no
Financial innovation	Enquête Emploi (labour survey)	20% of total cost	0,2	no

Source: Delbecque & Nayman (2010), Giorgio-Marrano, Haskel & Wallis (2009).

1.3 Intangible capital

Once investment data are estimated, we build intangible capital stocks using the following assumptions. First, investment data are deflated using product-level price indexes provided by INSEE. Using disaggregated price indexes is more accurate than overall value-added price index since intangible items prices (mostly related to service industries) have been growing faster than the rest of the economy since the 1990's. Second, in order not to underestimate capital stocks in early years, we linearly estimate investment back to 1970 in order to build a non-zero initial stock in 1980. Third, we build capital stocks using perpetual inventory method with depreciation rates taken from Giorgio-Marrano et al. (2009)[4].

1.4 Tangible capital, value-added and labour

Tangible capital stocks, value-added and labour data are provided by the STructural ANalysis (STAN) database from the OECD. The database provides us with NACE 1-digit industry level deflated tangible capital stocks and value-added as well as total labour (including self-employment) given in full time equivalent. These data are originally collected from national statistics offices by the OECD. Data are available since 1980 to 2007 on an annual basis.

As intangible capital data and OECD data use different classification and different levels of aggregation, we first aggregate intangible investment data at the French NES 16-industry level and transpose the NACE classification into NES in order to merge properly the two datasets. Although we waste detailed information when aggregating industries, that allows for clearer picture in data description. Moreover, the aggregation level of data in the STAN database does not allow for a more detailed information.

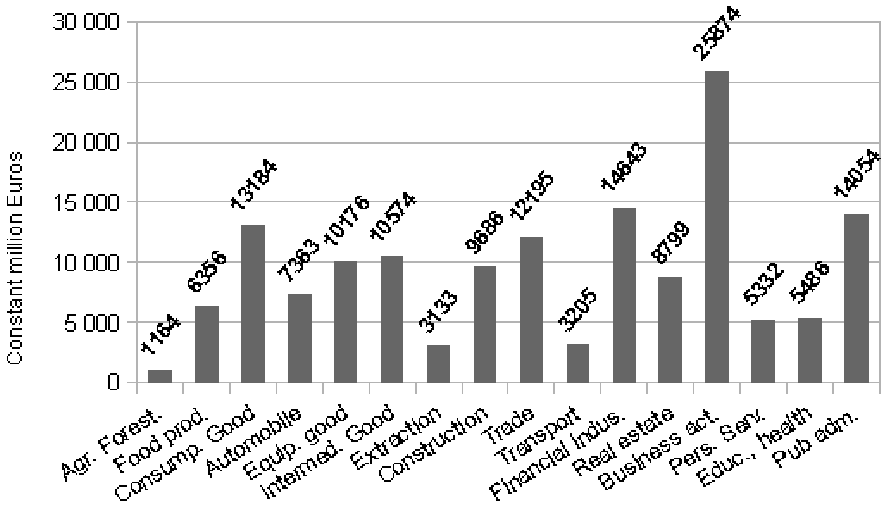
2 Investment structures and trends

It has long been argued that the increase in service activities in developed economies should lead to a joint increase in so-called "knowledge-intensive" or intangible inputs in the economy. The rationale being that service industries could be more intangible intensive than manufacturing industries. This holds true in absolute terms for some service industries, such as the business activities industry (NACE 74)[5] or the financial services industry (NACE64, 65 and 66) compared to other manufacturing industries (Figure 1).

However in relative terms, the picture is very different. When expressed in share of value-added, intangible investment in service industries are particularly low compared to manufacturing industries (Figure 2).

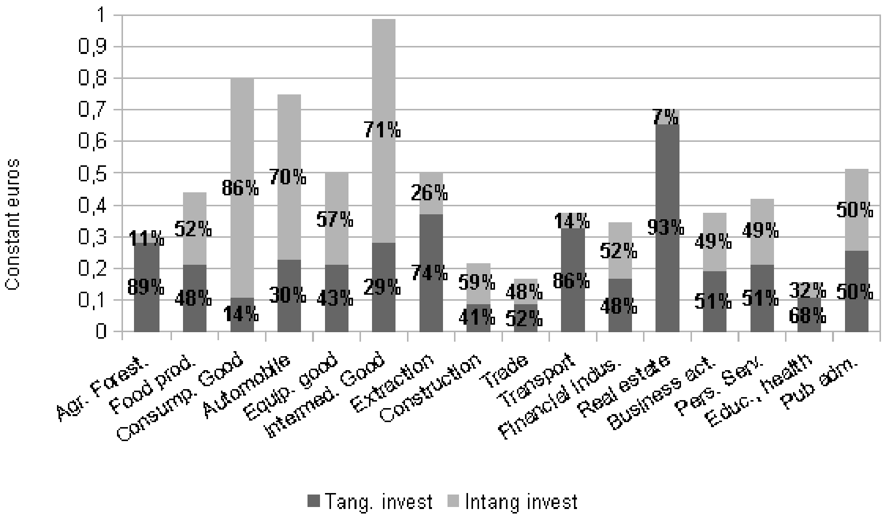
[4] We assume equal product-specific depreciation rates across industries.
[5] As mentioned in Section 1 industries are categorised following the French NES classification. In order to ease the reading, we relate these industries to the closest corresponding NACE industries.

Figure 1: Intangible investment in 2007 (constant million Euros)



Source: Authors' calculations.

Figure 2: Tangible and intangible investment in share of value-added in 2007 (constant terms)



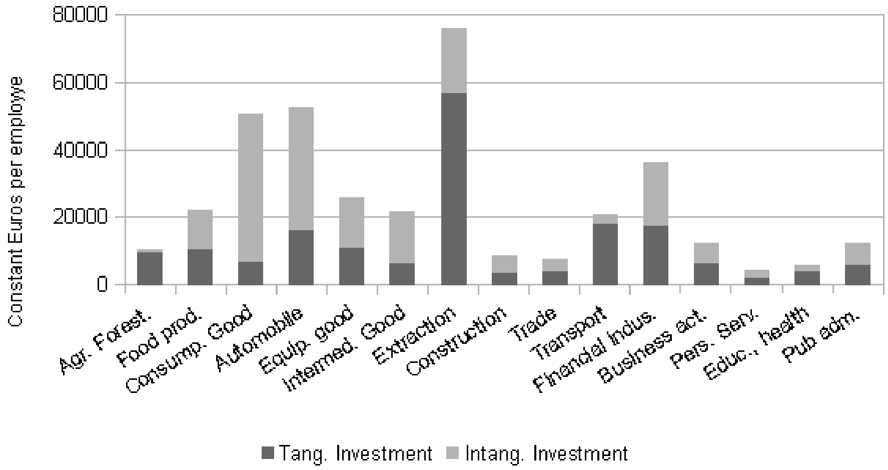
Source: Authors' calculations.

The car industry, the intermediate good industry and the consumption good industry are particularly intensive in intangible investment. More surprisingly, while service industries are supposed to be more intangible than tangible intensive we find strictly the opposite fact. In service industries (wholesale and retail trade, financial services, business activities and personal services) the budget dedicated to intangible investment is comparable to the amount invested in tangible capital. Meanwhile, in manufacturing industries (except extractive activities), investment in intangible capital is at least equal to investment in tangible capital, up to 6 times higher in the consumption good industry.

When expressed in terms of investment per employee the picture is, again, slightly different. Manufacturing industries being more labour intensive then service industries, differences in investment relative to labour are less pronounced than in the previous picture. Still, the manufacturing industry is more capital intensive than other industries (Figure 3). The real estate industry is not displayed on this figure. Tangible investment in the real estate industry is particularly high since it invests massively buildings for renting.

These first figures give a overall view of investment

Figure 3: Tangible and intangible intensity relative to labour input in 2007



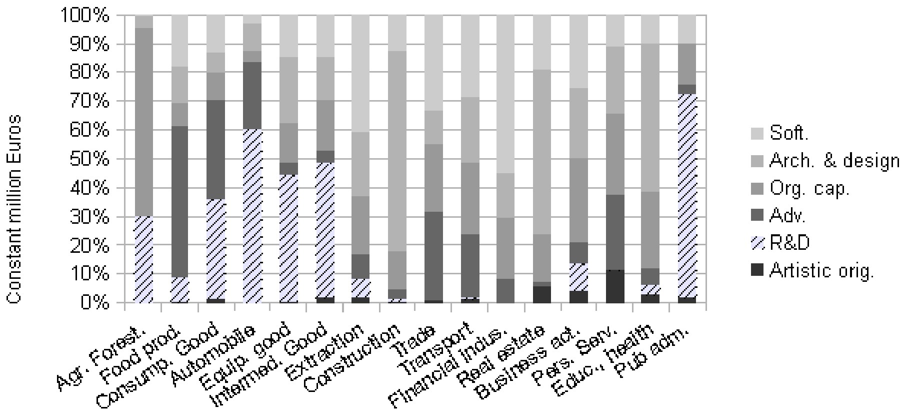
Source: Authors' calculations.

at the industry level and particularly concerning the distribution between tangible and intangible investment. We now go more in detail into the structure of investment at the 16-industry level. For each industry, we detail the share of each item in total intangible investment (Figure 4). As shown in Figure 4, investment structure is highly industry-specific. Manufacturing industries invest mainly in R&D, while relatively less in software and organisation compared to service industries. This yields two implications. First, when intangible investment is treated as an homogeneous aggregate much information are missing since it is made of several different items. Second, when dealing with investment performance, the industry-level analysis is of particular interest since investment structure differ widely across industries.

In dynamic terms, intangible investment has been increasing since 1980 in all industries. However, differences in growth path emerge between some of them. Within manufacturing industries, the case of the car industry in particularly striking. While investment was at the same level and has been increasing at the same pace as in the consumption good and intermediate good industries until the mid 1990's, it has been decreasing (relative to value-added) by 25% between 1993 and 2000. This sharp fall is mainly due to a comparable decrease in R&D investment by the car industry during the 1990's.

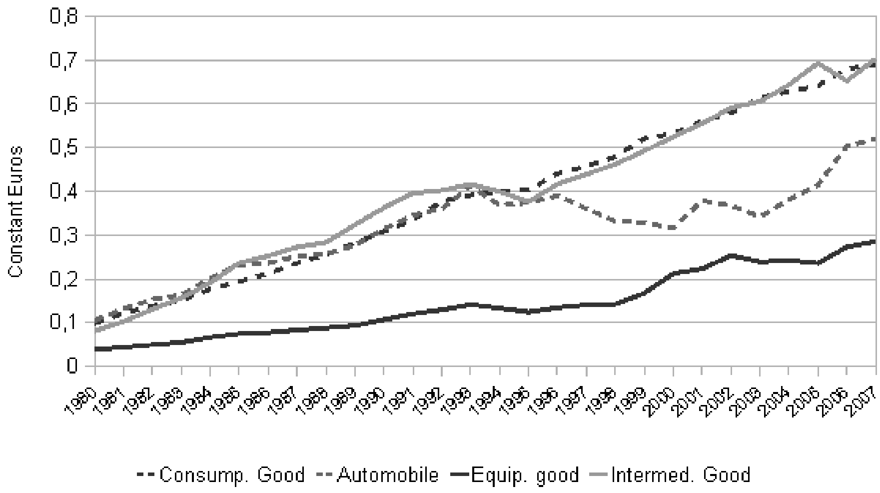
One mechanical explanation for this trend is the strong increase in output and value-added in the car industry during these years (+60% between 1996 and 2000), consequently, as investment grew slower than value-added, the ratio decreased. However, it also shows

Figure 4: Industry structure of intangible investment in 2007



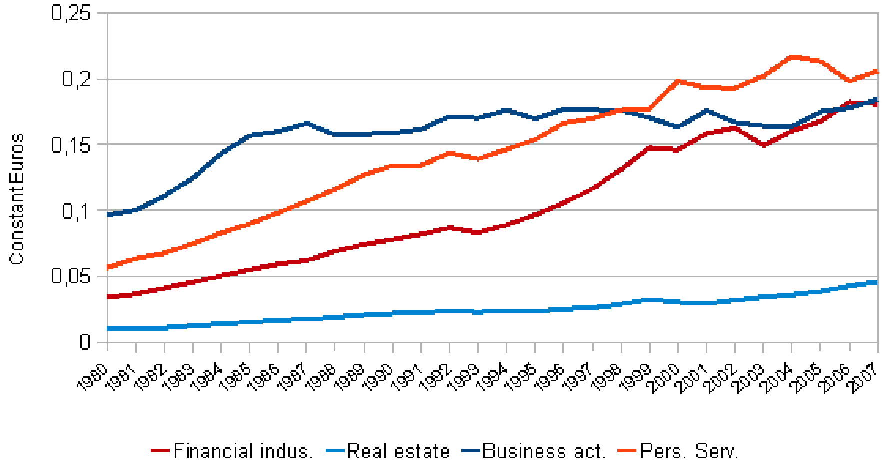
Source: Authors' calculations.

Figure 5: Intangible investment relative to value-added in main manufacturing industries



Source: Authors' calculations.

Figure 6: Intangible investment in share of value-added in main service industries



Source: Authors' calculations.

that despite a strong rise in value creation, the investment in innovative products and processes in the the French car industry has not been promoted.

The increasing trend of intangible investment is also clear in the service industry. The financial industry has experienced a strong rise in investment during the 1990's, mainly due to the increase in computer software in the production process. Personal services industry is also increasingly intangible, more than all other service industries.

The business activity industry displays a slightly different picture. Intangible investment has risen faster than in the other industries during the 1980's but has remained constant relative to value-added since the early 1990's.

3 Advanced analytical study

So far we have characterised intangible items individually. However, complementarity and combinations between assets could arise and thus need to be assessed. We now draw a more detail picture of intangible assets running a principal component analysis in order to highlight combined characteristics amongst items.

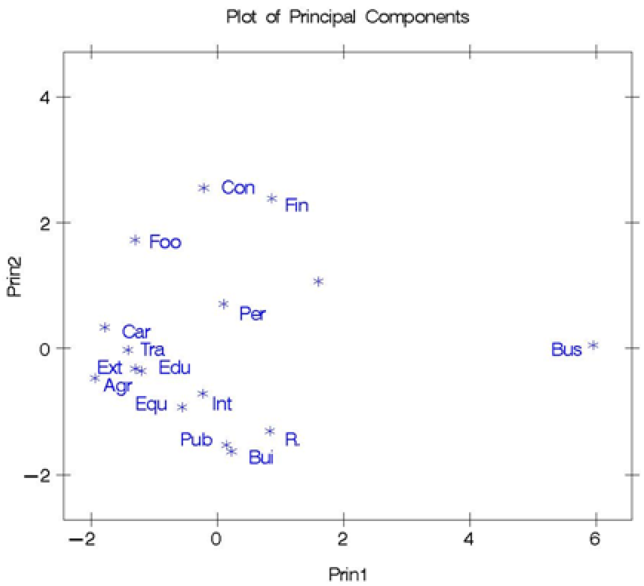
3.1 Overall principal component analysis

Using the partial correlation matrix (accounting for partial effect of time trend) we find that the first three principal components account for more than 80% of total dispersion (Appendix A).

All variables have positive coefficients in the first principal component (PC, thereafter). However, advertising and R&D have very low coefficients in this index. Advertising is the most important items of the second component with a very high coefficient (0,83), followed by software. The third component is mainly based on the R&D item, again with a very high coefficient (0,94). Following, we define three indexes, an overall index, an advertising index and an R&D index.

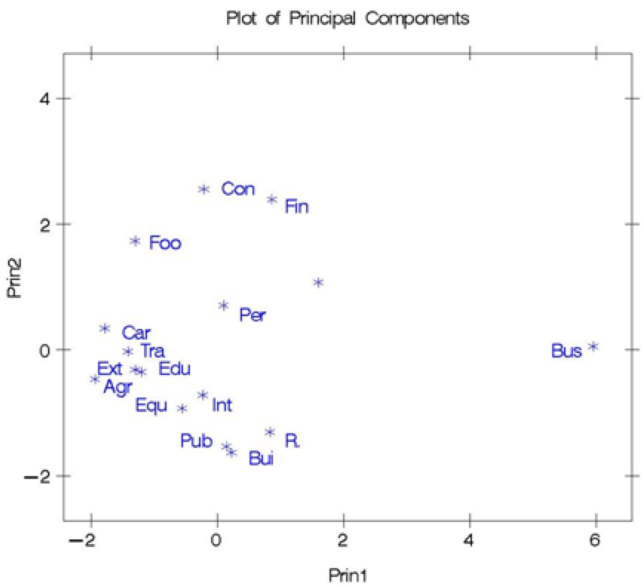
Figures 7 and 8 display the individual dispersion on the first and second principal component and the first and third principal component respectively. On the first principal plane, the business services industry is high on the first axis due to high overall innovation index followed by other service industries (Trade, real estate, financial services, public administration or personal services). Owing to this ranking, the car industry, the extraction industry, equipment, intermediate and con-

Figure 7: Plot of industries on the first principal plane



Source: Authors' calculations.

Figure 8: Plot of industries on the second principal plane



Source: Authors' calculations.

sumption good industries are little innovative due to the small weight of R&D in the overall index. On the second axis displaying advertising index, food industry, consumption goods industry and trade industry rank high due to large advertising assets. Financial services and personal services also have high score due to significant investment and assets in software.

The second principal plane displays the industry dispersion on the first and the third component. The vertical axis represents R&D-driven innovation index. There is a clear distinction between manufacturing industries (consumption goods, intermediate goods, equipment goods and cars) ranking high on the axis and service industries taking smaller values. However, public administration, as mentioned in the previous section, is large contributor to total R&D investment and has the largest score on the third index.

3.2 Industry-specific principal component analysis

We also run principal component analyses for each industry in order to build industry-specific innovation indexes. Besides previous PCA results, we assume that indexes may differ from an industry to another. Indeed we find different weights for each asset in the general PCA and in separate PCA (see Appendix A and C). For instance, the first two principal components for the car industry represent 1) "technological innovation", with large contributions from design and R&D; 2) "product launching innovation" dominated by advertising associated to organisation and software. In the meantime, the first two indexes for the trade industry are an "overall innovation index" with all items entering positively, and an "image and communication index" with large contribution of advertising, artistic originals and software[6]. For each industry, we will use the scores in the first two principal components in production function estimations in the following section. Using endogenous indexes has two main advantages. First, it accounts for empirical asset associations and complementarity. Second, it is not correlated to other variables avoiding collinearity issues.

4 Intangible investment and performance

We now turn to the analysis of factor contribution to growth. To that aim we explicitly estimate a Cobb-Douglas production function using labour and tangible capital as well as intangible capital as input factors. The Cobb-Douglas production function type has long been used in innovation analysis (see for instance Hall & Mairesse (1995) or Hall et al. (2009)) and despite its simple form, allows for direct interpretation in terms of contribution to value creation.

We apply the log-log form of the production function (Eq. 3) to our dataset, covering both cross-country and time dimension:

$$logY_{it} = \alpha_i + \beta_1 logL_{it} + \beta_2 logK_{it} + \beta_3 logI_{it} + \delta_t + u_{it} \tag{4}$$

Where β_n are coefficients to be estimated, u is a non-random error term defined below, and i and t subscripts denote industry and time respectively. We allow for both industry invariant specificities in the α term and common time shocks in the δ term.

4.1 Panel data estimations

We estimate these parameters using panel data regressions due to the presence of two dimensions in the dataset (industries and time). Industry-level data such as value added, labour and capital stocks are persistent over time. In such cases, the error term has a particular form and can be split into two parts, the autoregressive and the stochastic:

$$\begin{aligned} E(u_i^2 t) &= \sigma_{it} \\ E(u_{it}u_{jt}) &= \sigma_{ij} \\ u_{it} &= \rho_i u_{i,t-1} + \epsilon_{it} \end{aligned}$$

and

$$\begin{aligned} E(\epsilon_{it}^2) &= 0 \\ E(u_{i,t-1}\epsilon_{jt}) &= 0 \\ E(\epsilon_{it}\epsilon_{jt}) &= \phi_{ij} \\ E(\epsilon_{it}\epsilon_{j}) &= 0 for s \neq t \\ E(u_{i0}) &= 0 \\ E(u_{i0}u_{j0}) &= \sigma_{ij} = \phi_{ij}/(1-\rho_i\rho_j) \end{aligned}$$

In order to account for persistence in data, the production function is estimated using autoregressive two stage procedures. We first estimate the autoregressive parameter ρ through Ordinary Least Squares (OLS):

$$\hat{\rho} = \frac{\sum_{t=2}^{T} \hat{u}_{it}\hat{u}_{i,t-1})}{\sum_{t=2}^{T} \hat{u}_{i,t-1}^2}$$

with $i = 1, 2, ..., N$

The autoregressive characteristics is then removed taking weighted differences:

$$y_{it} - \hat{\rho}_i y_{i,t-1} = \sum_{k=1}^{p}(X_{itk} + \hat{\rho}_i X_{i,t-1,k})\beta_k - \hat{\rho}_i u_{i,t-1}$$

[6] Note that contrary to the overall principal component analysis, the industry-specific PCA is determined on the time dimension only.

As displayed in Section 2 manufacturing and service industries are not equally intensive in intangibles. It is reasonable to assume that intangible investment contributions in the service industries, may have different impacts both in constant and trends. For that reason, we estimate separately manufacturing industries (Table 2) and service industries (Table 3).

We first estimate a baseline model for manufacturing industries, including labour, tangible capital as well as intangible capital, all taken in logs (Table 2, Column A). All three coefficients are positive and significant at the 1% level. Amongst the three variables, labour has the highest contribution to growth followed by intangible capital and tangible capital, while the overall model explains 58% of total variance.

Following, we include alternatively four individual intangible variables instead of the total amount, namely, software, lagged R&D, advertising and organisation capital (column B to E). We find positive contribution for all but R&D with large contribution from organisation capital compared to other intangible inputs. The negative coefficient associated to R&D is surprising, especially for the manufacturing industry. We will investigate further this result in the disaggregated analysis.

Finally, we include the four intangible inputs together in the estimation (column F). Software capital has a positive contribution while advertising and R&D have negative impacts, though very small. Organisation capital turns out to be no longer significant when all variable are included together. This result may be due to light collinearity between software and organisation capital assets as shown in Appendix B.

The negative coefficient obtained on advertising and R&D are to be interpreted carefully. Positive or negative coefficients do not state about theoretical or potential effects of inputs on value-added rather about the empirical and effective contribution of these factors. More precisely, R&D itself may yield positive effect on value creation. However, the empirical results found in this first set of estimations show that, despite high amounts of R&D in the manufacturing industry, they may not have been allocated properly, resulting in an relative inefficient output.

Given the large differences in investment structure between industries, we now focus on the service industries only (Table 3). Results in column A shows quite unstable results on the tangible investment parameter with the aggregate intangible indicator. Moreover, intangi-

Table 2: Production function estimation – Manufacturing industries (Panel data first-order autoregressive)

	A	B	C	D	E	F
Intercept	6,27 ***	6,50 ***	6,66 ***	7,82 ***	6,58 ***	7,62 ***
	0,53	*0,76*	*0,66*	*0,56*	*0,83*	*0,66*
Labour	0,50 ***	0,54 ***	0,22 ***	0,51 ***	0,31 ***	0,36 ***
	0,04	*0,07*	*0,06*	*0,05*	*0,06*	*0,04*
Tangible	0,17 ***	0,26 ***	0,35 ***	0,22 ***	0,13 *	0,13 ***
	0,04	*0,06*	*0,06*	*0,05*	*0,08*	*0,04*
Intangible	0,25 ***					
	0,02					
Proc inv.						
Prod inv.						
Software		0,13 ***				0,15 **
		0,02				*0,05*
R&D -2			–0,06 ***			–0,03 ***
			<0,01			*<0,01*
Advert.				0,02 ***		–0,03 *
				<0,01		*0,02*
Org. cap.					0,30 ***	0,08
					0,04	*0,07*
R-sq.	0,58	0,55	0,64	0,41	0,56	0,72
# Periods	22	22	22	22	22	22
# Cross-section	9	9	9	9	9	9

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively. Standard deviations in italics.

Source: Authors' calculations.

Table 3: Production function estimation – Service industries (Panel data first-order autoregressive)

	A	B	C	D	E	F
Intercept	9,45***	3,81 ***	5,33 ***	6,24 ***	6,53 ***	9,14 ***
	0,4	*1,11*	*0,66*	*0,48*	*0,57*	*0,82*
Labour	1,21 **	0,92 ***	0,91 ***	1,13 ***	1,06 ***	0,69 ***
	0,06	*0,12*	*0,09*	*0,08*	*0,1*	*0,11*
Tangible	0,08	0,51 ***	0,41 ***	0,26 ***	0,25 ***	0,11 *
	0,06	*0,1*	*0,06*	*0,04*	*0,05*	*0,07*
Intangible	-0,04					
	0,05					
Proc inv.						
Prod inv.						
Software		0,01				0,29 ***
		0,03				*0,05*
R&D -2			-0,04 ***			-0,05 ***
			<0,01			*<0,01*
Advert.				0,05 **		-0,46 ***
				0,02		*0,03*
Org. cap.					0,06	0,13 *
					0,04	*0,08*
R-sq.	0,82	0,8	0,84	0,84	0,83	0,96
# periods	22	22	22	22	22	22
# cross-sections	6	6	6	6	6	6

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively. Standard deviations in italics.

Source: Authors' calculations.

ble assets indicators appear non significant in the regressions. Specifying production functions with intangible assets as a homogeneous factor is not appropriate to service industries taken together.

We thus turn to the analysis of individual assets taken independently (column B to E) and altogether (column F). Whereas coefficients are low when assets are included individually, their magnitude increases when added in the same estimation. Software and organisation capital have a strong positive contribution while advertising has a highly negative coefficient. Collinearity tests show that only light collinearity occurs when including all variables together between software and organisation (Appendix B).

These first results yield the following preliminary conclusions. First, as industries are heterogeneous in asset structures, they are also heterogeneous in assets contribution to value-added. Whereas intangible assets in manufacturing industries contribute positively to value creation, either taken independently or aggregated as a whole, their effect is less clear when considering service industries. Second, the way to aggregate intangible assets is not straightforward as shown by the results displayed in Table 3 and needs to be further investigated. Third the inner specification of production functions may differ between industries due to differences in production patterns.

In order to deepen the detailed industry analysis, we focus on specific industries from both manufacturing and services industries through time series analyses.

5 Time-series industry-specific estimations

We disaggregate industries focusing on the eight largest French industries in terms of intangible investment (car, consumption goods, intermediate goods, equipment goods, trade, financial services, business services and public administration). We sequentially estimate the contribution of four intangible assets, namely, software, R&D, advertising and organisation capital. Results are presented in tables 4 to 7 in order to compare the effect of each item across industries.

First, software is found to play a significant and positive role in the car industry and in financial services. This reflects the increasing importance of computing processes and automated processes in both car manufactur-

Table 4: Industry-specific estimations – Software (First-order autoregressive)

	A Car indus	B Consum. Good	C Iterm. Good	D Equip. Good	E Trade	F Fin. indus	G Busin. Services	H Pub. Adm.
Intercept	1,69	9,26**	6,27*	-4,16	-3,85*	7,73***	6,06***	-1,20
	3,5	*4,13*	*3,65*	*3,62*	*2,1*	*0,65*	*1,57*	*1,65*
Labour	0,35	-0,12	-0,36	-0,22	-0,02	0,82 **	1,45***	1,82***
	0,45	*0,52*	*0,32*	*0,43*	*0,21*	*0,38*	*0,19*	*0,24*
Tangible	0,61	-0,01	0,27	1,44***	1,35***	0,26***	0,28*	0,87***
	0,38	*0,43*	*0,33*	*0,36*	*0,23*	*0,07*	*0,01*	*0,15*
Software	0,30 *	0,11	0,05	-0,23*	-0,09	0,09**	0,01	-0,1**
	0,13	*0,11*	*0,09*	*0,12*	*0,05*	*0,02*	*0,03*	*0,04*
R-sq.	0,96	0,62	0,84	0,63	0,98	0,97	0,99	0,98

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively.

Source: Authors' calculations.

ing and financial activities (from ATM to automated risk analysis and trading). Software seem to have a small negative impact in public administration, although largely compensated by labour. The implementation of computing processes in French public administration may have had some drawbacks. Entry costs and temporal inefficiencies may incur when running-in new software and applications. Finally, the negative impact of software in the equipment good industry is somehow puzzling, though very small compared to tangible capital.

We now turn to the contribution of R&D (Table 5). Since trade and financial services industries do not report any spending in this item, no results are displayed in Column E and F. As expected R&D plays a positive role in value creation in the car industry and the consumption good industry. The coefficient associated to R&D in the estimated production function for the car industry equals more than half the contribution of labour or tangible capital. Not only, these two industries have invested massively in R&D but this investment has been efficient in terms of value creation. Conversely, Despite large investment, the intermediate good and the equipment good industries display non-significant or negative contribution of R&D to value-added. This result does not imply that R&D leads to negative effects per se, rather that the way investment was conducted was inefficient.

Although the definition of R&D in the business services industry is not straightforward and amounts are small compared to other items, it has a positive impact on value creation.

Finally, we find no significant effect of R&D invest-

Table 5: Industry-specific estimations – R&D (First-order autoregressive)

	A Car indus	B Consum. Good	C Iterm. Good	D Equip. Good	E Trade	F Fin. indus	G Busin. Services	H Pub. Adm.
Intercept	-0,85	14,31***	-6,78	1,53			4,30***	1,42
	2,8	2,81	5,37	6,82			1,47	1,27
Labour	0,76*	0,47*	-0,84***	0,37			1,21***	1,33***
	0,42	0,29	0,25	0,56			0,18	0,39
Tangible	0,70**	-0,65**	1,69***	1,15			0,39***	0,62***
	0,33	0,31	0,54	0,81			0,12	0,13
R&D	0,42***	0,32***	-0,32**	-0,1			0,09**	0,02
	0,14	0,08	0,14	0,3			0,03	0,08
R-sq.	0,83	0,77	0,75	0,48			0,99	0,97

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively.

Source: Authors' calculations.

ment in the public sector. This result is not surprising since most of the R&D activity in the public sector is produced within universities, but the results of research activities are applied in the private sector. Consequently, when analysing industries independently from one another, the link between R&D producers and final user is lost.

Table 6 displays results when estimating the contribution of advertising to value-added. Although we would expect positive effect of advertising in car, consumption good and trade industry, results displayed for these industries are not significant. However, this results is not totally surprising. Whereas advertising may have a positive effect at the micro level in modifying market shares amongst firms in the same industry, its effect at the industry level is less clear. Indeed, assuming constant real market size, a positive effect of advertising at this level of aggregation would point out potential competition between industries.

Nevertheless, the equipment good industry and the financial services industry display a positive sign in the coefficient associated to advertising. The effect is sizeable in the case of the equipment good industry, but the contribution of the other factors are unstable depending on the specification.

Finally, organisation capital contributes positively to value creation when significant (Table 7). The contribution is also high compared to other intangible assets. This result confirms previous findings (Table 2 and 3) where we found that organisation plays a strong role in manufacturing industries.

Although assessing the joint effect of each intangible

Table 6: Industry-specific estimations – Advertising (First-order autoregressive)

	A Car indus	B Consum. Good	C Iterm. Good	D Equip. Good	E Trade	F Fin. indus	G Busin. Services	H Pub. Adm.
Intercept	-2,68	9,27**	-1,01	7,73**	-0,36	7,34***	6,02***	-1,84
	3,66	3,59	4,42	2,8	1,72	0,5	1,76	1,12
Labour	0,04	-0,13	-0,70***	0,84***	0,09	0,68**	1,47***	1,79***
	0,41	0,41	0,23	0,09	0,13	0,32	0,24	0,18
Tangible	1,02**	-0,09	1,08**	0,01	0,98***	0,27***	0,3*	0,95***
	0,45	0,42	0,42	0,29	0,2	0,06	0,15	0,1
Advertising	0,16	0,19	-0,27*	0,46***	0,02	0,14***	0,01	-0,19***
	0,21	0,16	0,14	0,11	0,07	0,03	0,09	0,04
R-sq.	0,73	0,63	0,74	0,83	0,99	0,97	0,99	0,99

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively.

Source: Authors' calculations.

Table 7: Industry-specific estimations – Organisation capital (First-order autoregressive)

	A Car indus	B Consum. Good	C Iterm. Good	D Equip. Good	E Trade	F Fin. indus	G Busin. Services	H Pub. Adm.
Intercept	5,07*	10,51***	6,03	-3,39	-2,47	7,51***	6,15***	-1,76*
	2,59	2,98	3,67	3,02	1,91	0,54	1,62	1,01
Labour	0,72***	0,2	-0,53	-0,24	0,09	0,65*	1,48***	2,32***
	0,25	0,34	0,33	0,39	0,12	0,32	0,23	0,22
Tangible	0,14	-0,21	0,33	1,46	1,21***	0,24***	0,28*	1,02***
	0,3	0,32	0,34	0,32	0,21	0,07	0,14	0,11
Organisation	0,68***	0,27**	-0,01	-0,36	-0,07	0,15***	0,01	-0,31***
	0,12	0,11	0,14	0,16	0,08	0,04	0,10	0,06
R-sq.	0,94	0,63	0,8	0,68	0,99	0,98	0,99	0,99

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively.

Source: Authors' calculations.

[7] Some collinearity diagnostics are displayed in appendix A. All diagnostics are available upon request.

asset would be of great interest, multi-collinearity issues does not allow for such estimations[7]. Indeed, some intangible items are strongly correlated over time within industries. If used simultaneously in the production function specification their estimated coefficient would be biased. However, asset associations and complementarity need to be addressed in this analysis. In order to tackle multi-collinearity issues, we use indexes obtained from industry-level principal component analyses instead of individual intangible items in the regressions (Section 3 and Appendix C). Although we waste information on the magnitude of contributions to value-added, we ensure to estimate robust coefficients and to highlight asset combinations.

Although synthetic indexes may differ from an industry to another, in some cases, we find common types of asset associations. The results of the PCA show comparable first components for the consumption good industry and the equipment good industry or the trade industry and the financial services industry. The composition of each index is described in Appendix C.

In these specifications, when significant, we find positive effects of labour and tangible capital, except for the labour input in the consumption good industry (Table 8). Results for the car industry show a significant positive effect of technological innovation (Column A). This confirms previous results emphasising the importance of R&D especially in the car industry. The associ-

Table 8: Production function estimation with industry-innovation indexes (First-order autoregressive)

	A Car indus	B Consum. Good	C Iterm. Good	D Equip. Good	E Trade	F Fin. indus	G Busin. Services	H Pub. Adm.
Labour	-0,42	-0,69***	-0,23	0,43***	0,49***	0,49***	1,29***	1,77***
	0,29	0,13	0,16	0,11	0,17	0,26	0,17	0,28
Tangible	1,09***	0,58*	1,16**	0,12	0,91***	0,45***	0,46	0,56***
	0,23	0,35	0,43	0,41	0,05	0,04	0,14	0,09
Technol. innovation (R&D, Design)	0,05***							
	10							
Product launching innovation (Advert., org. software)	0							
	20							
Proc (+) vs prod (-) innovation		0,01		0,04***				
		0,01		0,01				
Overall Innovation index		-0,02		0,03	-0,01***			
		0,01		0,02	0,00			
Product innovtion index			-0,03**					
			0,01					
Process innovation index			0,00					
			0,01					
Image and communication innovation					0,02**	0,02***	0,00	
					0,01	0,01	0,00	
Non-R&D innovation						-0,01*	-0,01***	-0,01***
						0,00	0	0
Non-infrastructure related innovation								-0,01*
								0,01
R-sq.	0,87	0,95	0,95	0,81	0,99	0,97	0,99	0,99

***, ** and * denoting estimators significant at the 1%, 5%, and 10% confidence limit respectively.

Source: Authors' calculations.

ation of R&D and engineering design is a means of value creation in this industry. However, the second index associated to product launching innovation is not significant.

Results for the intermediate goods and equipment goods industries tend to yield same conclusions (Column C and D). Innovation in processes performs better than innovation in products. Best value-creation comes from the way goods are produced rather than from the goods themselves. These two industries face particularly fierce competition on the international markets not only from cost competitive countries (emerging and transition countries) but also from innovative countries (Germany). Putting the emphasise on organisation and efficient production processes seems to be the way for French firms in these two industries to keep creating value.

The trade industry and the financial services industry exhibit similar production patterns in both traditional input factors and innovation (Column E and F). The first two principal components for these industries are related to overall innovation (where all assets have a positive contribution) and "image and communication innovation" mainly based on advertising, artistic originals and design. In both industries, while innovation as a whole has a slightly negative contribution, we find positive effect of the communication index. Not only communication is a predominant factor in the trade industry but it also contribute to create value. However, advertising alone seems not to be sufficient, while associated to art and design, the effect proves significant. In the financial industry, although advertising, art and design are not major items, they play a positive role in the production. This tends to confirm that, despite the specificities of the financial industry (in both inputs and output) the characterisation of the production process is comparable to the trade industry.

Finally, the analysis of the public administrations yields more detailed comments than in the previous set of estimations. The two indexes obtained from the PCA relate to non-R&D innovation and non-infrastructure innovation. Public entities are large providers of both R&D, through universities, and infrastructures. The results show that non-R&D innovation and non-infrastructure innovation do not yield positive effects in this sector. The other way around R&D and architecture and positive contributors to value creation in the public sector.

6 Conclusion

Using national account data, we estimate new data covering intangible investment and capital for 118 industries in France for the period 1980-2010. In that we intend to deepen the understanding of innovation patterns at a disaggregate level. First, we extensively document structures and trends in intangible items across industries during the period. Second, we analyse the contribution of several intangible assets jointly with tangible capital and labour for a key number of industries.

This work provides several valuable results. Intangible investment and innovation characteristics are highly industry-specific. While manufacturing industries are intensive in R&D and engineering design, service industries invest massively in computer software and organisation. This brings evidence on the fact that R&D is not the only type of innovation and that other types should be considered, especially in the service industry. Moreover, trends in investment differ across industries. Turning to the analysis of assets contribution to value creation, again, we find large heterogeneity in results. R&D does play a significantly positive role in the car industry while the effect is not so clear in other manufacturing industries. Besides, computer software and organisation capital have strong positive effects in some manufacturing and service industries. The joint effect of intangible assets is not clear since significant collinearity arise in the regression when including several assets. In order to solve this issue, we use endogenous composite innovation indexes build from a principal component analysis. This tool has two main benefits. First, the indexes obtained are not correlated with other variables. Second, it provides empirical indexes built from industry-specific intangible assets structure. These indexes also highlight combination and complementarity between assets. Although these results are stable for most industries, some other display very sensitive results.

These findings yield 3 conclusions. First, analysing intangible capital and investment is of prime interest since we observe heterogeneity that needs to be addressed. Second, this heterogeneity has to be taken into account when implementing innovation policies. Indeed, specific innovation should be promoted in the industry where performs best. The relative positive effect of R&D in some manufacturing industries also shows that the amount of R&D itself is not directly linked to performance. Consequently, the way innovation is managed within firms has to be precisely addressed. Third, firms innovation practices should also focus an performance driving assets and asset combination. To that aim, precise research analysis and objectives should be implemented within dedicated innovation departments.

Further work would deepen the study of industry complementarity and innovation transfers. More precisely, the role played by the public sector is not clearly identified and will possibly be analysed closer.

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A Principal component analysis

Table A-1: Eigenvalues of the Partial Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	2.71	1.54	0.45	0.45
2	1.17	0.14	0.19	0.65
3	1.02	0.42	0.17	0.82
4	0.6	0.16	0.1	0.92
5	0.44	0.38	0.07	0.99
6	0.06		0.01	1

Source: Authors' calculation

Table A-2: Eigenvectors

	1st PC	2nd PC	3rd PC	4th PC	5th PC	6th PC
	Overall innovation index	Communication vs technological innovation	R&D innovation			
Adv.	0.07	0.83	0.24	0.3	0.39	-0.08
Arch. & eng. design	0.43	-0.42	-0.14	0.18	0.77	-0.03
Artistic Orig.	0.49	-0.06	0.11	0.62	-0.42	0.42
Org. Cap.	0.58	0.04	0.07	-0.16	-0.28	-0.74
R&D	0.01	-0.24	0.94	-0.2	0.09	0.1
Soft. & database	0.48	0.27	-0.13	-0.65	0.03	0.5

Source: Authors' calculation

We run a principal component analysis on the whole industry sample in order to characterise intangible assets across industries and to compare industries based on assets combinations. The three first component account for more than 80% of total data dispersion. We thus concentrate on these components. All items enter the first component positively with very low scores for R&D and advertising. We call this index "Overall innovation index". The second index, called "Communication vs technological innovation) is mainly made of advertising and software with a positive signs and design and R&D with negative signs. Industries having large values of R&D assets for instance will have small score in this index. The third index is mostly R&D innovation.

B Collinearity Diagnostics

We use the condition index proposed by Belsley et al. (1980) in order to test for potential collinearity between input factors in the different specifications. On empirical basis, Belsley (1993) states that with maximum condition indexes taking values between 1 and 10, no collinearity occurs. When condition index equals 30 to 100 potentially severe collinearity issues arise. Besides, high values of variance proportions (above 0.5) associated to high condition indexes show which variables tend to be collinear.

Table B-1: Collinearity Diagnostics – Manufacturing industries

			Variance Proportion		
Number	Eigenvalue	Condition Index	Tangible capital	Labour	Intangible capital
1	2,3113	1,0000	0,0633	0,0637	0,0742
2	0,4168	2,3548	0,1457	0,1678	0,9253
3	0,2719	2,9157	0,7909	0,7685	0,0005

Table B-2: Collinearity Diagnostics: Manufacturing industries

			Variance proportion					
Number	Eigenvalue	Condition Index	Advertising	Org Cap	R&D	Software	Tangible cap.	Labour
1	3,6767	1,0000	0,0189	0,0023	0,0107	0,0026	0,0185	0,0126
2	0,8600	2,0677	0,0944	0,0052	0,1040	0,0300	0,0087	0,0000
3	0,7981	2,1463	0,2217	0,0004	0,0075	0,0077	0,1083	0,1146
4	0,3859	3,0867	0,5684	0,0039	0,2959	0,0012	0,0000	0,1023
5	0,2576	3,7782	0,0152	0,0020	0,0542	0,0014	0,8545	0,3826
6	0,0217	13,0000	0,0813	0,9862	0,5276	0,9597	0,0100	0,3880

Table B-3: Collinearity Diagnostics: Service industries

			Variance Proportion		
Number	Eigenvalue	Condition Index	Tangible capital	Labour	Intangible capital
1	1,99610	1,00000	0,07560	0,07630	0,07640
2	0,79630	1,58320	0,77550	0,10220	0,01150
3	0,20760	3,10110	0,14890	0,82150	0,91210

Table B-4: Collinearity Diagnostics: Service industries

			Variance proportion					
Number	Eigenvalue	Condition Index	cap	empl	adv	poc	rd	soft
1	3,7543	1,0000	0,0095	0,0066	0,0068	0,0017	0,0109	0,0000
2	0,9600	1,9790	0,4466	0,0011	0,0211	0,0000	0,2058	0,0004
3	0,8253	2,1329	0,4253	0,0029	0,0027	0,0000	0,3975	0,0006
4	0,3104	3,4777	0,0880	0,0509	0,1390	0,0235	0,0156	0,0206
5	0,1387	5,2019	0,0001	0,4230	0,2669	0,0058	0,3694	0,0157
6	0,0127	17,1971	0,0305	0,5155	0,5636	0,9690	0,0008	0,9609

C Industry level principal component analysis

Table C-1: Eigenvectors – Consumption goods industry

	Process vs product innovation	Overall Innovation index	Prin3	Prin4	Prin5	Prin6
Advertising	−0,19	0,58	−0,36	−0,06	−0,49	0,50
Architecture and engineering design	0,55	−0,06	0,45	0,34	−0,02	0,62
Artistic originals	−0,53	0,32	0,16	0,55	0,52	0,11
Organisation capital	0,36	0,54	0,04	−0,52	0,56	0,01
R&D	−0,12	0,37	0,74	−0,09	−0,41	−0,35
Software and database	0,49	0,35	−0,31	0,55	−0,10	−0,48

Table C-2: Eigenvectors – Car industry

	Technological innovation	Product launching innovation	Prin3	Prin4	Prin5	Prin6
Advertising	−0,16	0,65	−0,10	0,53	−0,12	0,50
Architecture and engineering design	0,57	0,06	0,15	−0,42	0,26	0,64
Artistic originals	0,58	0,07	−0,05	0,04	−0,79	−0,16
Organisation capital	0,13	0,57	−0,58	−0,36	0,24	−0,37
R&D	0,54	−0,04	0,08	0,62	0,48	−0,29
Software and database	−0,05	0,50	0,79	−0,18	0,01	−0,31

Table C-3: Eigenvectors – Equipment goods industry

	Process vs product innovation	Overall innovation index	Prin3	Prin4	Prin5	Prin6
Advertising	0,44	0,28	−0,41	0,66	0,33	−0,15
Architecture and engineering design	−0,46	0,03	0,54	0,54	0,31	0,33
Artistic originals	0,43	0,20	0,64	−0,26	0,39	−0,38
Organisation capital	−0,25	0,70	0,12	0,14	−0,54	−0,35
R&D	0,47	0,35	0,14	−0,09	−0,24	0,76
Software and database	−0,36	0,52	−0,33	−0,42	0,54	0,16

Table C-4: Eigenvectors – Intermediate goods industry

	Product innovation index	Process innovation index	Prin3	Prin4	Prin5	Prin6
Advertising	0,49	0,26	−0,40	0,25	0,62	−0,27
Architecture and engineering design	−0,45	0,25	0,53	0,29	0,57	0,21
Artistic originals	0,50	−0,03	0,53	0,58	−0,34	−0,14
Organisation capital	−0,08	0,66	0,23	−0,35	−0,18	−0,59
R&D	0,54	0,22	0,29	−0,51	0,12	0,55
Software and database	−0,11	0,62	−0,37	0,35	−0,36	0,46

Table C-5: Eigenvectors - Trade

	Overall innovation index	Image and communication innovation	Prin3	Prin4	Prin5	Prin6
Advertising	0,45	0,53	0,16	-0,51	0,49	0,00
Architecture and engineering design	0,39	-0,59	0,45	0,31	0,45	0,00
Artistic originals	-0,39	0,51	0,61	0,45	0,08	0,00
Organisation capital	0,53	0,06	0,41	-0,05	-0,74	0,00
R&D	0,00	0,00	0,00	0,00	0,00	1,00
Software and database	0,47	0,34	-0,48	0,66	0,05	0,00

Table C-6: Eigenvectors – Financial services

	Overall innovation index	Communication index	Prin3	Prin4	Prin5	Prin6
Advertising	0,38	0,72	0,26	0,53	0,00	0,00
Architecture and engineering design	0,40	-0,69	0,15	0,58	0,00	0,00
Artistic originals	0,00	0,00	0,00	0,00	1,00	0,00
Organisation capital	0,60	-0,05	0,51	-0,61	0,00	0,00
R&D	0,00	0,00	0,00	0,00	0,00	1,00
Software and database	0,58	0,07	-0,81	-0,11	0,00	0,00

Table C-7: Eigenvectors – Business services industry

	Non R&D innovation	Image and communication index	Prin3	Prin4	Prin5	Prin6
Advertising	0,49	0,24	0,27	-0,66	-0,40	0,16
Architecture and engineering design	0,47	-0,07	-0,51	0,37	-0,18	0,59
Artistic originals	0,13	0,72	-0,31	-0,13	0,60	-0,01
Organisation capital	0,57	0,08	0,02	0,37	-0,13	-0,71
R&D	-0,21	0,60	0,45	0,49	-0,32	0,22
Software and database	0,38	-0,25	0,61	0,16	0,57	0,27

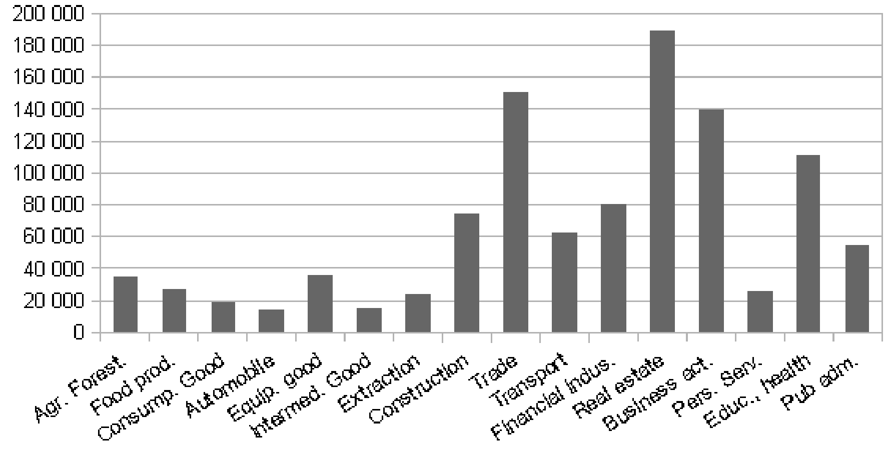
Table C-8: Eigenvectors – Public administration

	Non R&D innovation	Non infrastructure-related innovation	Prin3	Prin4	Prin5	Prin6
Advertising	0,52	0,20	0,03	-0,82	-0,06	-0,07
Architecture and engineering design	0,41	-0,41	0,40	0,10	0,63	0,30
Artistic originals	0,23	0,46	0,72	0,32	-0,30	-0,12
Organisation capital	0,39	0,43	-0,43	0,33	0,45	-0,41
R&D	-0,25	0,61	-0,04	-0,08	0,27	0,69
Software and database	0,54	-0,11	-0,36	0,30	-0,48	0,49

D Other data

In order to get a clearer picture of industry composition, we display a chart with industry-level value-added (Figure 9). Service industries are the highest contributors to total value-added in absolute terms.

Figure 9: Value added in 2007 (constant million Euros)



Source: Authors' calculations.