INFRASTRUCTURES AND ICT. MESUREMENT ISSUES AND IMPACT ON ECONOMIC GROWTH

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A B S T R A C T

The paper revises the impact of infrastructures and Information and Communication Technologies (*ICT*) on economic growth. It takes Spain as a reference case due to the accessibility to capital services estimates. The Spanish database allows the measurement of the impact on growth of three *ICT* assets (software, hardware and communication) and six different types of infrastructures (roads, railways, airports, ports, as well as urban and water infrastructures). As a first step, the paper recommends the adjustment of the National Accounts (NA) figures. The rationale for the adjustment relies on the need to recognize explicitly the services provided by public capital, not fully included in NA. However, the results show that the methodological differences related to government services flows are not quantitatively important as they give very similar estimates in terms of the pace of economic growth in Spain.

Keywords: *ICT*, Infrastructures, growth accounting

JEL: O40, O47, O52

The paper revises the impact of infrastructures and Information and Communications Technologies (*ICT*) on Spanish economic growth. It makes use of the Fbbva/Ivie capital services database recently released (Mas, Pérez and Uriel (2005)) which follows closely OECD (2001a, b) recommendations. The paper also addresses the problem posed by the presence of publicly owned assets. After offering an alternative to the standard approach, it carries out a growth accounting exercise considering explicitly three types of *ICT* capital assets (software, hardware and communications) and six different types of infrastructures (roads, ports, railways, airports, and water and urban infrastructures).

The point of departure is twofold. On the one hand, there is the role played by infrastructures on the US productivity slowdown of the seventies and eighties - highlighted in his seminal article by Aschauer (1989a). His contribution deserved a great deal of attention not only in the US but in other countries as well[1]. Most papers make use of econometric estimations of either production or cost functions, where public capital enters explicitly as an argument. The lack of agreement on the value of the output infrastructure elasticity was the dominant result, ranging from 0.73 in Aschauer (1989b) to even negative values obtained by some authors (see Sturm, Kuper and Haan (1996) for a review). The lack of adequate information on capital services provided by the different types of assets did not allow contrasting the econometric results with those obtained from a growth accounting framework. Their present availability for Spain led us to fill this gap.

The second reference is the intensive, as well as extensive, work done since the beginning of the nineties on the contribution of *ICT* to economic growth. While infrastructures displayed a leading role on the US productivity slowdown of the seventies and eighties, *ICT* accumulation was identified as the major responsible factor of the US productivity upsurge since the mid nineties[2]. However, similar impacts were not observed –at least not with generality- in most of the European Union (EU) countries. Seemingly, significant impact was confined to countries with an important presence of the *ICT* producing sector[3].

In the case of Spain the debate on the role played by infrastructures on economic growth deserved a great deal of attention during the nineties. The issue at hand was not only how to promote growth but, most importantly, the consequences of the different public capital endowments among the Spanish regions in the (lack of) convergence of per capita regional incomes. Over the late nineties the slowdown of Spanish labor productivity, contrasting with the upsurge in the USA, put *ICT* capital in the center of the discussion, substituting somehow the previous prominence of infrastructures in the growth debate.

Within this general framework, the paper follows the next structure. Section 1 sketches the growth accounting framework taken as reference. Section 2 reviews the treatment given to publicly owned assets by National Accounts as well as its implications. Section 3 summarizes the data used, and section 4 illustrates the consequences of using the standard approach to the internal rate of return determination. Section 5 presents the results and section 6 concludes.

1. The Growth Accounting Framework

Suppose that the production function recognizes three different types of capital

$$Q_t = Q_t(KP_t^{ICT}, KP_t^{INF}, KP_t^{O}, HL_t, B) \tag{1}$$

where Q_t is real Gross Value Added; KP_t stands for a volume index of capital services with the superscripts *ICT, INF* and *O* referring respectively to *ICT*, Infrastructures and Other forms of (non residential) capital; HL_t represents employment (hours worked); and B indicates the level of efficiency in the use of productive factors.

Standard growth accounting assumptions allow us to obtain:

$$\Delta \ln Q_t = \bar{w}^{HL} \Delta \ln HL + \bar{w}^{ICT} \Delta \ln KP^{ICT} + \bar{w}^{INF} \Delta \ln KP^{INF} + \bar{w}^{O} \Delta \ln KP^{O} + \Delta TFP$$

$$\bar{w}_t^{\chi} = 0.5\left[w_t^{\chi} + w_{t-1}^{\chi} \right] \text{ for } \chi = HL;\ ICT;\ INF;\ O \tag{2}$$

Without imposing any additional conditions, the labor share in equation (2) is defined as

$$w_t^{HL} = \frac{\sum_i CE_{i,t}}{TC_t} \tag{3}$$

where CE_i is labor compensation in the i^{th} sector and TC_t is total cost defined as

$$TC_t = \sum_j \sum_i VCS_{j,i,t} + \sum_i CE_{i,t} \tag{4}$$

Where $VCS_{j,i,t}$ *is* the value of the capital services provided by asset *j* in industry *i.* defined as:

$$VCS_{j,i,t} = cu_{j,t}\, KP_{j,i,t-1} \quad (5)$$

with $cu_{j,t}$ representing the user cost of asset j[4]. The share on total cost of each of the three types of capital assets is defined as

$$w_t^{\chi'} = \sum_{j \in \chi'} \sum_i \frac{VCS_{j,i,t}}{TC_t} \quad (6)$$

With $\chi' = ICT, INF, O$. The growth rate of each group of variables in (2) is computed as a Törnqvist index. Thus, for *ICT* capital, the growth rate is defined as

$$\Delta \ln KP^{ICT} = \ln KP_t^{ICT} - \ln KP_{t-T}^{ICT} = \frac{1}{T}\left[\sum_{j=s,h,c} \sum_i \bar{v}_{j,t}^{ICT} (\ln KP_{j,i,t} - \ln KP_{j,i,t-T})\right]$$

$$\bar{v}_{j,t}^{ICT} = 0.5\left[\frac{VCS_{j,i,t}}{\sum_{j=s,h,c} \sum_i VCS_{j,i,t}} + \frac{VCS_{j,i,t-T}}{\sum_{j=s,h,c} \sum_i VCS_{j,i,t-T}}\right] \quad (7)$$

With s = software; h = hardware; and c = communications. The growth rate of infrastructures and of the remaining (other) forms of capital is computed in a similar manner.

If additional assumptions are imposed, namely: 1. Constant returns to scale (CRS) in the production function (1); 2. optimizing behavior by agents; 3. competitive markets; and 4. perfect foresight (in the sense that the ex-post rate of return implicitly computed by national accountants exactly matches the ex-ante rate) then, total cost equals total revenue ($TC_t = PQ_t$) so that either term can be safely used interchangeably in equations (3) to (6). Additionally, in this case, $w_t^{HL} + w_t^{ICT} + w_t^{INF} + w_t^{O} = 1$ and equation (6) measures the output elasticity of each type of capital.

On the User Cost

The user cost expression in equation (5) can adopt different specifications. Let ´s assume –following Jorgenson and Landfeld (2004)- that it is given by

$$cu_{j,t} = p_{j,t-1} \left(r_t - \pi_{j,t} + (1 + \pi_{j,t})\, \delta_{j,t}\right) \quad (8)$$

with $p_{j,t-1}$ representing the price of asset j, and $\pi_{j,t}$ its rate of variation; r_t is the nominal rate of return (common to all assets); and $\delta_{j,t}$ is asset j depreciation rate.

The next step is the determination of r_t in (8), either with an exogenous or an endogenous procedure. According to the former one the rate of return must be related, in one way or another, to the market nominal rates of interest. By contrast, the endogenous procedure obtains the internal rate of return by equating Gross Operating Surplus (GOS) to capital revenues.

The endogenous approach has the main advantage of conforming to main stream assumptions, namely that the production function presents constant returns to scale (*CRS*) in a perfectly competitive environment. The need to fulfill these assumptions becomes also its main inconvenient. To this, Schreyer, Diewert and Harrison (2005) add an additional problem. According to these authors, an endogenous rate of return for the total economy cannot be calculated because there is no independent estimate of *GOS* for government assets.

Before turning to this point, let's follow Jorgenson and Landfeld (2004) again and further assume that r_t is a weighted average of the nominal interest rate and the internal rate of return, ρ_t:

$$r_t = \beta_t \, i_t + (1 - \beta_t) \, \rho_t \tag{9}$$

That is, r_t combines an exogenous component (i_t) together with an endogenous one, ρ_t. Equation (9) shows a standard financial structure for private firms, where the market interest rate reflects debt financing and the endogenous rate reflects equity financing. With this assumption, equation (8) becomes:

$$cu_{j,t} = p_{j,t-1} \, (\beta_t \, i_t + (1 - \beta_t) \, \rho_t - \pi_{j,t} + (1+\pi_{j,t}) \, \delta_{j,t}) \tag{10}$$

We now turn to the problem posed by the presence of public assets.

2. The treatment of public assets

The presence of assets owned by the public sector poses a puzzle, at least potentially, for the implementation of growth accounting. The reason lies on the National Accounts (*NA*) practices. National Accounts do not assign a net return to the flow of services provided by public capital. The only recognized flow is fixed capital consumption. Jorgenson and Landfeld (2004) address the issue in the following terms: **“**While the existing accounts do treat government expenditures on capital goods as investment, they include only a partial value for the services of government capital by counting the value of depreciation on government capital (no value is included for the services of nonprofit capital)…The present treatment of government capital implicitly assumes that the net return to government capital is zero, despite a positive opportunity cost”. And they continue, “the net return to the capital stock must (be) estimated and added to depreciation to develop a service value. This estimation raises conceptual issues relating to the appropriate opportunity cost and empirical issues in estimating this cost" (pg. 12).

The above paragraph summarizes the main issues, with the following important implications:

1. The Gross Operating Surplus (*GOS*) figures provided by National Accounts are underestimated because the value of capital services provided by public capital is not fully considered.

2. Consequently, the value of output is also underestimated in *NA* figures, affecting both its level and rate of growth.

3. If the standard (endogenous) approach is used when computing the rate of return, points 1 and 2 above will have, at least potentially, consequences on: a) the user costs; b) the input shares; c) the growth accounting results

Let's assume that the property of a given asset *j*, is divided between the public and private sectors. Thus, $KP_{j,t} = KP^{p}_{j,t} + KP^{g}_{j,t}$ -where the superscripts *p* and *g* denote respectively private and government property of asset *j*. According to National Accounts (*NA*), the Gross Operating Surplus (*GOS*) is computed as:

$$GOS^{NA} = GOS^{NA,p} + \sum_{j}\sum_{i}\delta_{j,t}\, p_{j,t-1} KP^{g}_{j,i,t-1}$$

That is, *GOS* in the *National Accounts* is *GOS* of the private sector plus depreciation of government assets. From an analytical perspective, and under the assumptions of the standard approach, the private sector *GOS* will equal private sector capital services. So, $GOS^{NA,p} = \sum_{j}\sum_{i} cu_{j,t} KP^{p}_{j,i,t-1}$ and it follows that:

$$GOS_t^{NA} = \sum_j \sum_i cu_{j,t} KP_{j,i,t-1}^p + \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g \tag{11}$$

Thus, according to *NA*, the services provided by a given amount of capital depend upon its private or public nature. Even so, most researchers are not aware of the specific methodology followed by *NA*. This is especially true when the internal rate of return (denoted by ρ^{NA}) is computed from an equation such as (12):

$$GOS_t^{NA} = \sum_j \sum_i cu_{j,t}^{NA} \left[KP_{j,i,t-1}^p + KP_{j,i,t-1}^g \right] = \sum_j \sum_i p_{j,t-1} \left[\beta_t i_t + (1-\beta_t)\rho_t^{NA} - \pi_{j,t} + (1+\pi_{j,t})\delta_{j,t} \right] \left[KP_{j,i,t-1}^p + KP_{j,i,t-1}^g \right] \tag{12}$$

The fact that the usual way of computing the internal rate of return is incorrect does not impair this procedure from being applied once the public ownership of some assets is fully recognized. As an alternative, the internal rate could be computed reordering equation (11) to get

$$\begin{aligned} GOS_t^{NA} - \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g &= \sum_j \sum_i cu_{j,t}^R KP_{j,i,t-1}^p = \\ &= \sum_j \sum_i p_{j,t-1} \left[\beta_t i_t + \left(1-\beta_t\right) \rho_t^R - \pi_{j,t} + \left(1+\pi_{j,t}\right) \delta_{j,t} \right] KP_{j,i,t-1}^p \end{aligned} \tag{13}$$

The superscript *R* refers to the revised approach proposed here, while the superscript *NA* refers to the standard (endogenous) approach. Once the revised internal rate, ρ^R, has been computed according to (13) one can apply Nordhaus (2004) basic principle for measuring non-market activities: "Non-market goods and services should be treated as if they were produced and consumed as market activities. Under this convention, the prices of non-market goods and services should be imputed on the basis of the comparable market goods and services" (pg. 5). Thus, if one assumes the same rental price for capital $cu_{j,t}$ independently of who owns the asset[5], we can revise the

National Accounts figures, in order to obtain a revised Gross Operating Surplus estimate, GOS^R, in the following way:

$$GOS_t^R = GOS_t^{NA} + \sum_j \sum_i cu_{j,t}^R KP_{j,i.t-1}^g - \sum_j \sum_i \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g \quad (14)$$

Growth Accounting Implications

As already indicated, the explicit recognition of the provision of capital services by public assets –beyond capital consumption- affects the value, as well as the growth rates, of two of the variables involved in any growth accounting exercise: value added and capital input.

Let's $(PQ)_t^{NA}$ be the aggregated nominal value added in year t according to National Accounts, while $(PQ)_t^R$ denotes the revised nominal value added corresponding to the revised approach proposed here. Equation (15) defines nominal value added in branch i, $(PQ)_{i,t}^R$, as:

$$(PQ)_{i,t}^R = (PQ)_{i,t}^{NA} + \sum_j cu_{j,t}^R KP_{j,i,t-1}^g - \sum_j \delta_{j,t} p_{j,t-1} KP_{j,i,t-1}^g \quad (15)$$

Revised real value added in sector i, $Q^R{}_{i,t}$, is obtained using National Accounts deflators (P^{NA}):

$$Q_{i,t}^R = (PQ)_{i,t}^R / P_{i,t}^{NA}; \qquad P_{i,t}^{NA} = (PQ)_{i,t}^{NA} / Q_{i,t}^{NA}$$

The shares of each input in the value of output –that is, its elasticities- are also affected. For any capital asset j, the output elasticity would be given by [16] according to the standard approach, and by [17] by the revised one.

$$w_{j,t}^{NA} = \sum_i \frac{cu_{j,t}^{NA} KP_{j,i,t}}{\sum_i (PQ)_t^{NA}} \tag{16}$$

$$w_{j,t}^{R} = \sum_i \frac{cu_{j,t}^{R} KP_{j,i,t}}{\sum_i (PQ)_t^{R}} \tag{17}$$

The rate of growth of aggregate real output (Q^R) is computed using a Törnqvist index as given by (18)

$$\frac{1}{T}\left[\ln Q_t^R - \ln Q_{t-T}^R\right] = \frac{1}{T}\left\{\sum_i 0.5\left[\frac{PQ_{i,t}^R}{\Sigma_i (PQ)_{i,t}^R} + \frac{PQ_{i,t-T}^R}{\Sigma_i (PQ)_{i,t-T}^R}\right]\left[\ln Q_{i,t}^R - \ln Q_{i,t-T}^R\right]\right\} \tag{18}$$

The growth rate of capital is given by an equation similar to (7) where *VCS* is computed in (5) using the revised user cost, ρ^R, obtained from (13). Before comparing –in section 4 below- the results provided by both approaches the next section provides a brief description of the data characteristics and sources.

3. The data

Fundación Banco Bilbao Vizcaya Argentaria (FBBVA) and the *Instituto Valenciano de Investigaciones Económicas* (Ivie) elaborate the Spanish capital database. The methodology follows two OECD Manuals: *Measuring Capital* and *Measuring Productivity*[6]. The Volume Index of Capital Services, KP_t, is constructed using a Winfrey S-3 Retirement Function and a Hyperbolic Age-Efficiency Function. The FBBVA-Ivie estimates consider 43 industries and 18 asset types. Table 1 presents the classification of industries and table 2 the 18 asset categories.

TABLE 1: Classification of industries

Industry	Description	Code CNAE-93 = Code NACE Rev. 1
1	Agriculture, hunting and forestry	01-02
2	Fishing, fish farming and related service activities	05
3	Mining and quarrying of energy producing materials	10-12
4	Mining and quarrying except energy producing materials	13-14
5	Manufactures of food products, beverages and tobacco	15-16
6	Manufacture of textiles and wearing apparel; dressing and dyeing of fur	17-18
7	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	19
8	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20
9	Manufacture of pulp, paper and paper products; publishing, printing and reproduction of recorded media	21-22
10	Manufacture of coke, refined petroleum products and nuclear fuel	23
11	Manufacture of chemicals and chemical products	24
12	Manufacture of rubber and plastic products	25
13	Manufacture of other non-metallic mineral products	26
14	Manufacture of basic metals and fabricated metal products, except machinery and equipment	27-28
15	Manufacture of machinery and equipment n.e.c.	29
16	Manufacture of electrical and optical equipment	30-33
17	Manufacture of transport equipment	34-35
18	Manufacture of furniture; manufacturing n.e.c.; Recycling	36-37
19	Electricity, gas and water supply	40-41
20	Construction	45
21	Wholesale and retail trade; repairs	50-52
22	Hotels and restaurants	55
 23 24 25 26 27	Transport and storage and communication Road infrastructures Railways infrastructures Airport infrastructures Port infrastructures Rest of Transport and storage and communication	60-64
28	Financial intermediation	65-67
29	Real estate activities	70
30	Renting of machinery and equipment and other business activities	71-74
 31 32 33 34 35 36 37 38 39 40	Public administration Road infrastructures Water infrastructures Railways infrastructures Airports infrastructures Ports infrastructures Urban infrastructures Non-market education Non-market health Non-market social work Rest of public administration	75, 80P, 85P
41	Market education	80P
42	Market health and social work	85P
43	Other community, social and personal services	90-93

Source: FBBVA and own elaboration

TABLE 2: Classification of Assets

Product	Description	Code CNPA96 = Code CPA96
1	Agricultural, livestock and fish products	01-05
2	Metal products	28
3	Machinery and mechanical equipment	29
4	Office machinery and computer equipment	30
5	Communications	313, 32, 332-333
6	Other machinery and equipment n.e.c	31 (ex. 313), 331, 334-335, 36
7	Motor vehicles	34
8	Other transport material	35
9	Dwellings (Residential Construction)	45P
	Other constructions	45P
10	Road infrastructures	
11	Water infrastructures	
12	Railway infrastructures	
13	Airport infrastructures	
14	Port infrastructures	
15	Urban infrastructures	
16	Other constructions n.e.c.	
17	Software	72
18	Other products n.e.c.	Rest of codes

Source: FBBVA and own elaboration

The information is available on a year basis for the period 1964-2002[7]. The FBBVA-Ivie database makes a clear distinction between assets owned by the private sector and those owned by the public sector[8]. The latter appear under the heading *Public Administration* in table 1 consisting of ten different industries (31-40). It is interesting to note that infrastructures enter twofold in the Spanish estimates: as assets in table 2, and also as industries in table 1. Infrastructures owned privately (such as highways or some water infrastructures) are included either in the *Transport, Storage and Communication* industry (branches 23-26) or *Electricity, Gas and Water Supply* (branch 19). Publicly owned infrastructures are assigned to the branch *Public Administration* in table 1 (branches 31-36), together with non-market health, education, social work and the rest of public administration.

Table 3 will contribute to clarify the way investment in each type of infrastructure is treated in the Spanish capital estimates. For each year *t* we have a matrix with 18 different types of assets -detailed in table 2- in columns, and the 43 industries in rows. In Spain, urban infrastructures are built only by the public sector. With respect to the remaining assets, either the private or the public sector can accumulate them. Take for example the asset “roads” in column 10. If the public administration is the active agent, we will record the amount invested in the row 31, *Road infrastructures*, under the *Public Administration* heading. However, if it is a private toll road we will record it in row 23 *Road infrastructures* under the heading *Transport, Storage & Communication*[9].

TABLE 3: Treatment of Infrastructures in the Spanish capital estimates. An illustration

Recording of year t investment in infrastructures

Year t (e.g. 2000)

	TYPES OF ASSETS									
INDUSTRIES			**Infrastructures**							
	1. Agric.	...	10 Road	11 Water	12 Railway	13.Airport	14.Port	15 Urban	...	18.Other
1. Agriculture, hunting &forestry										
2. Fishing										
...										
19. Electricity, gas & water supply				Private I						
…										
Transport, storage & communication										
23. Road infrastructures			Private I							
24. Railways infrastructures					Private I					
25. Airport infrastructures						Private I				
26. Port infrastructures							Private I			
27. Rest of transport, storage & communication										
...										
Public Administration										
31. Road infrastructures			Public I							
32.Water infrastructures				Public I						
33. Railways infrastructures					Public I					
34. Airport infrastructures						Public I				
35. Ports infrastructures							Public I			
36. Urban infrastructures								Public I		
...										
43. Other community, social & personal services										

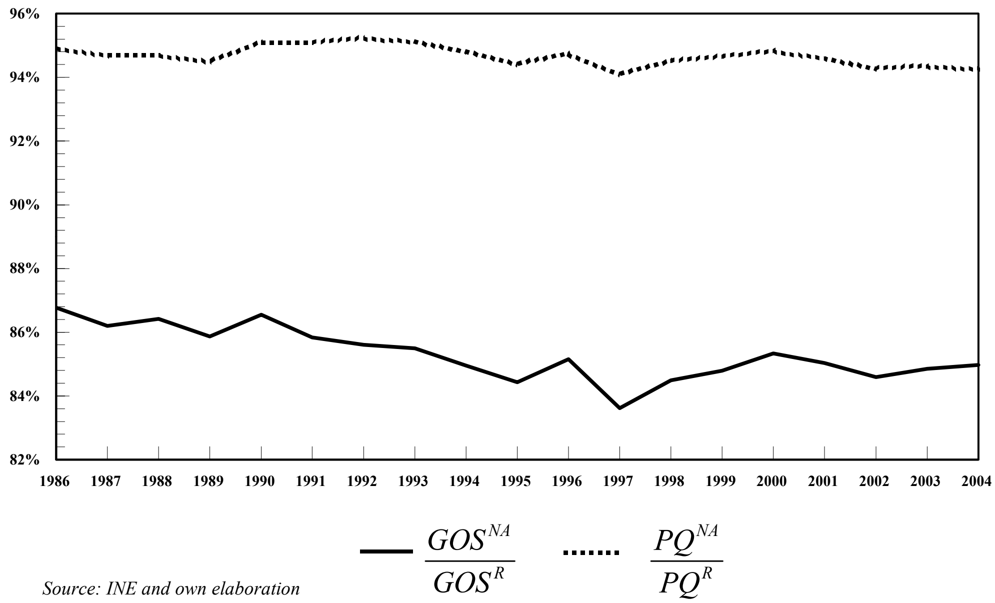
Source: FBBVA and own elaboration

The information for the variables GOS^{NA}, PQ^{NA} and Q^{NA} comes from the Spanish National Accounts released by the Spanish *Instituto Nacional de Estadística* (INE). We obtain the total values aggregating the forty three industries detailed in table 1. Since residential capital is not considered part of the definition of productive capital, we exclude two items from gross value added: namely, rents from dwellings and incomes from private household with employed persons[10]. The Bank of Spain publishes data for the nominal interest rates, i_t, and the ratio β_t. We use medium and long-term corporate loan rates as nominal interest rates and the ratio external funds/(external funds+equity), from a survey published yearly by the Bank of Spain's *Central Balance Sheet Office*, as a measure of β_t.

4. Implications of the two approaches

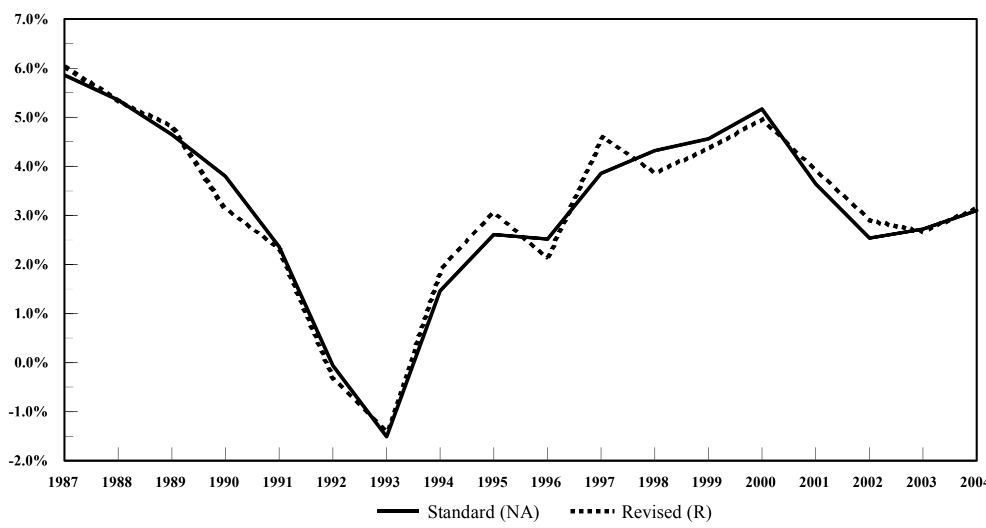
The choice between the standard *vs* the revised approach here proposed has consequences: *i*) for the levels of Gross Operating Surplus and Value Added; *ii*) for the growth rates of Value Added and Capital; and *iii*) for the estimated output elasticities of the factors of production[11]. Graph 1 plots the ratios between the two forms of computation for the two variables, *GVA* and *GOS*. GVA data for the revised approach are given by equation (15) and those for *GOS* from (14). National Accounts underestimate the *GVA* figures by approximately 5%-6% and the *GOS* figures by 15%. In both cases the gap has increased since the mid nineties. However, these differences in levels are lower in terms of growth rates. Graphs 2 and 3 show that the differences in growth rates between the two approaches are practically non existing. Graph 4 illustrates the gap between the capital output shares, being around 3.5 percentage points higher in the revised approach (which includes the whole value of capital services provided by infrastructures) than in the standard one. Correspondingly, the labor share is 3.5 percentage points lower.

GRAPH 1.
Gross Value Added and Gross Operating Surplus. Ratio National Accounts / Revised (including infrastructures capital services) Approach



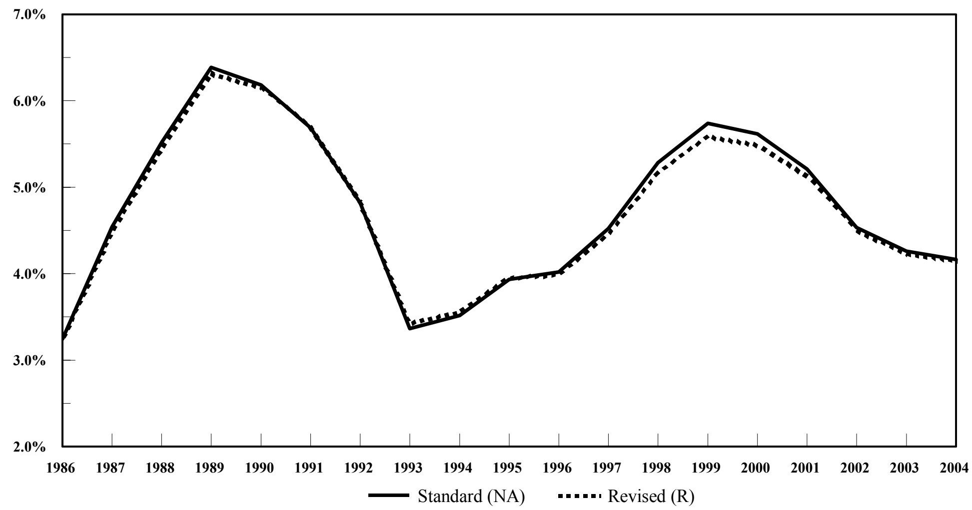
Source: INE and own elaboration

GRAPH 2.
Growth Rates of Value Added. Standard vs. Revised (including infrastructures capital services) Approach



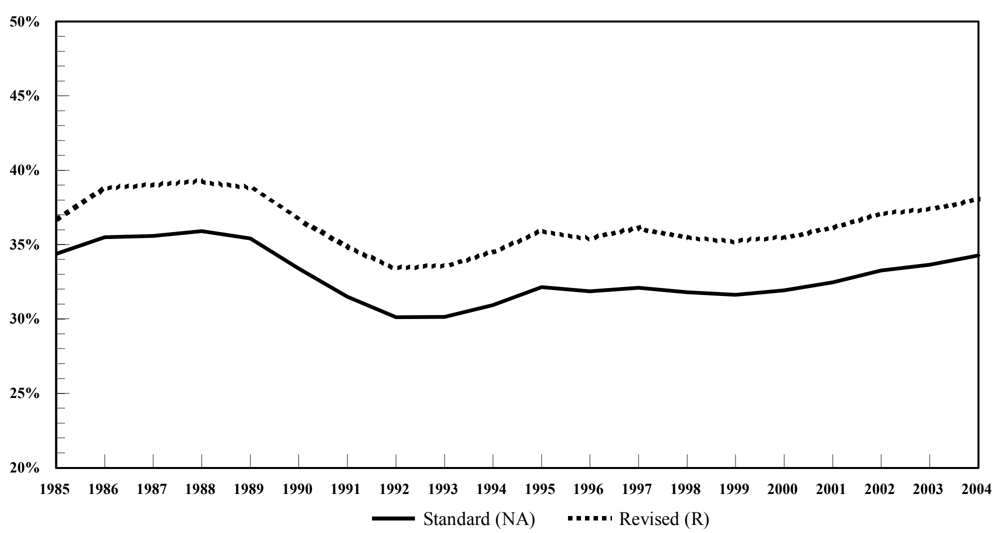
Source: INE and own elaboration

GRAPH 3.
Growth Rates of Capital. Standard vs. Revised (including infrastructures capital services) Approach



Source: FBBVA and own elaboration

GRÁFICO 4:
Capital output shares. Revised (including infrastructures capital services) vs. Standard



Source: INE, FBBVA and own elaboration

5. *ICT* and Infrastructures. Results

Before turning to the growth accounting results it is interesting to take a closer look at some of the factors lying behind. The first one is the user cost. Table 4 presents the results provided by both approaches as well as the differences between the two. The three first columns indicate that –according to the revised approach- the user cost has increased for all the assets included in the infrastructures and *ICT* groups, with the only exception of *Office machinery and computer equipment* (hardware for short). At the beginning of the period, the user cost was lower for infrastructures than for *ICT* capital as a consequence of both, lower prices indexes and lower unit user costs[12]. In contrast, in 2004 the user cost for hardware was lower than for infrastructures due to the strong price reduction of the former. In fact, while hardware experienced more than a four fold (4.1) accumulated price reduction, infrastructures prices increased almost by 40% (38.5%) between 1995 and 2004. However, and as expected, the unit user cost of *ICT* assets has always been higher than for infrastructures due to two combined effects: higher depreciation rates -as a result of shorter services lives- and capital losses originated by falling prices, especially in hardware. The remaining columns indicate that the user costs for *ICT* assets computed according to the revised approach are systematically higher than when using the standard procedure. However, note that the discrepancies are of a second order of magnitude.

As we mentioned above, most of the papers devoted to the analysis of the role of infrastructures on economic growth start by estimating an equation such as (1) –usually highlighting only infrastructure capital. They frequently impose constant returns to scale (*CRS*) and perfectly competitive markets. So the estimated coefficient is identified as the infrastructure's output elasticity. Under these assumptions, total cost (*TC*) equals total revenue (*PQ*) and equation (6) provides the expression for infrastructures' value added elasticity. Table 5 contains the values. As before, the first three columns show the results provided by the revised approach, while the last three columns provide the differences between the two.

TABLE 4: User cost. Infrastructures and ICT

Revised (including Infrastructures capital services) vs Standard

	Revised (R)			Standard (NA)			Discrepancy [(R) - (NA)]		
	1995	2000	2004	1995	2000	2004	1995	2000	2004
Infrastructures									
2.1 Road Inf.	0.115	0.120	0.153						
2.2 Water Inf.	0.127	0.136	0.172						
2.3 Railway Inf.	0.128	0.136	0.166						
2.4 Airport Inf	0.126	0.131	0.161						
2.5 Port Inf.	0.119	0.126	0.158						
2.6 Urban Inf.	0.120	0.126	0.160						
ICT									
4.2.3 Office machinery	0.473	0.187	0.102	0.446	0.178	0.096	0.027	0.009	0.006
4.2.4.1 Communications	0.249	0.271	0.226	0.225	0.250	0.205	0.024	0.021	0.021
4.3.1 Software	0.580	0.678	0.755	0.556	0.652	0.726	0.024	0.026	0.029

Source: FBBVA and own elaboration

TABLE 5: Capital Output shares

Revised (including Infrastructures capital services) vs Standard

	Revised (R)			Standard (NA)			Discrepancy [(R) - (NA)]		
	1995	2000	2004	1995	2000	2004	1995	2000	2004
Infrastructures	**0.057**	**0.053**	**0.060**						
2.1 Road Inf.	0.023	0.023	0.026						
2.2 Water Inf.	0.015	0.013	0.014						
2.3 Railway Inf.	0.009	0.008	0.010						
2.4 Airport Inf	0.002	0.002	0.002						
2.5 Port Inf.	0.003	0.003	0.003						
2.6 Urban Inf.	0.005	0.005	0.006						
ICT	**0.043**	**0.044**	**0.040**	**0.042**	**0.044**	**0.040**	**0.001**	**0.000**	**0.000**
4.2.3 Office machinery	0.012	0.009	0.008	0.012	0.009	0.008	0.000	0.000	0.000
4.2.4.1 Communications	0.022	0.023	0.019	0.021	0.023	0.018	0.001	0.000	0.001
4.3.1 Software	0.009	0.012	0.013	0.009	0.012	0.013	0.000	0.000	0.000
Rest	**0.259**	**0.258**	**0.280**	**0.279**	**0.275**	**0.303**	**-0.020**	**-0.017**	**-0.023**
TOTAL	**0.359**	**0.355**	**0.380**	**0.321**	**0.319**	**0.343**	**0.038**	**0.036**	**0.037**

Source: FBBVA and own elaboration

For total capital, the estimated gross value added elasticity is around 0.35-0.38, while for non-infrastructures non-*ICT* is approximately 0.1 of a percentage point lower. Infrastructures elasticity increased over the period, presenting values around 0.05-0.06 since 1995. This figure is very close to the one obtained by Mas *et al* (1996) for Spain (0.086) and higher than in Goerlich and Mas (2001) for the fifty Spanish provinces

(0.02). The aforementioned elasticities were computed from an econometric estimation of a production function equation similar to (1). The lower value of the elasticity when provincial data are used can be interpreted by the presence of spillover effects among contiguous territories. These figures reconcile the results obtained from the two alternative strategies, econometric estimation and growth accounting. However, it also contradicts previous results obtained by Mas *et al* (1996) where, after the recursive estimation of a production function, the elasticity diminishes and does not increase as it is now the case.

All things considered, the output elasticity of *ICT* assets is lower than that of infrastructures and it has remained fairly stable since 1995. The highest value corresponds to communications and the lowest to hardware, while software is the *ICT* asset showing the strongest elasticity increase. On its part, the last three columns indicate that the use of the standard approach does not have practical consequences on *ICT* assets elasticities, but it certainly does on the aggregate's as well as in the other's forms of capital.

The contribution of the different assets to output growth depends on two factors: their elasticity as well as their rate of growth. The latter ones appear in table 6. According to the revised version, in the first two columns, the rate of growth of total (non residential) capital has been rather strong in Spain, averaging over 4.5% during the period 1995-2004. *ICT* accumulation was even stronger, presenting two digits figures between the years 1995 and 2000. In period 2000-2004 it decelerated, from 11.2% to 7.5%, but still in a pretty fast range. Infrastructures annual rate of growth was one percentage point lower than total –and also less than a third of *ICT*´s- during the first subperiod. However, it experienced a slight recovery between 2000 and 2004, growing at a rate similar to total capital. The right hand side of table 6 informs us that the differences between the two approaches is almost nil[13], confirming the previous result presented in graph 3.

TABLE 6: Productive capital. Annual growth rates. Percentages

Revised (including Infrastructures capital services) vs Standard

	Revised (R)		Standard (NA)		Discrepancy [(R) - (NA)]	
	1995-2000	2000-2004	1995-2000	2000-2004	1995-2000	2000-2004
Infrastructures	**3.92**	**4.76**				
2.1 Road Inf.	4.43	4.28				
2.2 Water Inf.	2.60	2.03				
2.3 Railway Inf.	3.74	9.04				
2.4 Airport Inf	4.98	10.67				
2.5 Port Inf.	2.86	4.09				
2.6 Urban Inf.	5.77	4.95				
ICT	**11.18**	**7.53**	**11.25**	**7.55**	**-0.07**	**-0.02**
4.2.3 Office machinery	21.94	17.63	21.94	17.63	0.00	0.00
4.2.4.1 Communications	7.10	4.95	7.10	4.95	0.00	0.00
4.3.1 Software	9.14	4.71	9.14	4.71	0.00	0.00
Rest	**4.32**	**4.29**	**4.33**	**4.30**	**-0.01**	**-0.01**
Total	**4.98**	**4.54**	**5.08**	**4.57**	**-0.10**	**-0.03**

Source: FBBVA and own elaboration

We have now all the ingredients needed to move to growth accounting[14]. As already mentioned, infrastructures enter twice in the Spanish estimates: as assets in table 2, and also as industries in table 1. Therefore, from the perspective of the growth accounting framework, infrastructure capital affects the aggregate figures through its impact on two specific industries. Public infrastructures contribute to the growth rate of the value added generated by the *Public Administration* industry –and thus to aggregate value added- while privately owned infrastructures affect the growth rate of the *Transport, Storage and Communication* industry. Table 7 presents the result of the growth accounting exercise, taking as reference equation (2) but referred to labor productivity instead of total output. As before, the results for the revised approach are presented in the first three columns.

TABLE 7: Growth Accounting. Labor productivity

Revised (including Infrastructures capital services) vs Standard

	Revised (R)			Standard (NA)			Discrepancy [(R) - (NA)]		
	1995-2000 (a)	2000-2004 (b)	Acceleration (b)-(a)	1995-2000 (a)	2000-2004 (b)	Acceleration (b)-(a)	1995-2000 (a)	2000-2004 (b)	Acceleration (b)-(a)
1. Labor productivity growth (=2+6)	**-0.081**	**0.621**	**0.702**	**0.002**	**0.452**	**0.450**	**-0.083**	**0.169**	**0.252**
2. Contribution of capital endowments per hour worked (=3+4+5)	**0.329**	**0.731**	0.402	0.326	0.669	0.343	0.003	0.062	0.059
3. Infrastructures. Total	**-0.007**	**0.126**	**0.133**						
2.1 Road Inf.	0.009	0.042	0.033						
2.2 Water Inf	-0.020	-0.007	0.013						
2.3 Railway Inf	-0.003	0.057	0.060						
2.4 Airport Inf.	0.002	0.016	0.014						
2.5 Port Inf.	-0.003	0.004	0.007						
2.6 Urban Inf	0.009	0.014	0.005						
4. ICT	**0.312**	**0.211**	**-0.101**	**0.310**	**0.209**	**-0.101**	**0.002**	**0.002**	**0.000**
4.2.3 Office machinery	0.190	0.133	-0.057	0.190	0.133	-0.057	0.000	0.000	0.000
4.2.4.1 Communications	0.069	0.051	-0.018	0.067	0.049	-0.018	0.002	0.002	0.000
4.3.1 Software	0.053	0.027	-0.026	0.054	0.027	-0.027	-0.001	0.000	0.001
5. Rest of capital	**0.025**	**0.394**	**0.369**	**0.017**	**0.460**	**0.443**	**0.008**	**-0.066**	**-0.074**
6. TFP (=1-2)	**-0.410**	**-0.110**	**0.300**	**-0.324**	**-0.216**	**0.108**	**-0.086**	**0.106**	**0.192**

Source: FBBVA and own elaboration

During the years 1995-2000 labor productivity growth was slightly negative (-0.08%) but it recovered its pulse –though modestly- over the years 2000-2004 (0.62%). The negative rate of change in labor productivity during the second half of the nineties originated in the combination of two factors: a strong deceleration of the capital endowments per worker, together with a negative contribution of Total Factor Productivity (*TFP*) growth. Capital deepening slowdown affected all forms of capital, with the sole exception of *ICT* capital. For the remaining forms of capital their contribution was almost nil, being infrastructures contribution slightly negative.

Things changed in period 2000-2004. *ICT* capital deepening decelerated (from 0.312 to 0.211) while other forms of capital recovered their impulse. Especially noticeable was the increase experienced by infrastructures, which moved from a negative value (-0.007) in the years 1995-2000 to a positive one (0.126) in the last sub period. Even most important were the recovery of the non-infrastructures non-*ICT* capital (from 0.025 to 0.394) and the reduction of the negative contribution of *TFP* (from -0.410 to -0.110)[15].

The right hand side of table 7 provides further information. When we use the standard approach instead of the revised procedure: 1. the negative rate of change of labor productivity in period 1995-2000 turns slightly positive and the subsequent recovery is somewhat slower. As a consequence, the acceleration between the two subperiods is also lower; 2. the contribution of capital per hour worked is slightly smaller in both superiods, specially in 2000-2004; 3. *TFP* contribution to labor productivity growth shows a negative sign in both approaches. Notwithstanding, while over the period 1995-2000 *TFP* showed a more negative behavior if we use the revised methodology, in 2000-2004 the opposite result happened. 4. However, the most remarkable fact is the stability shown by the *ICT* contribution to productivity growth which is seemingly unaffected by the approach chosen.

6. Concluding remarks

New capital services data released by Fbbva/Ivie have made possible to carry out – improving and updating previous studies- an analysis of the impact of infrastructures and new technologies on Spanish growth. Used data include 43 industries and 18 different types of assets (including 6 types of infrastructures and 3 types of *ICT* capital). The chosen approach was growth accounting while most previous studies were forced to use –due basically to the lack of suitable data- an econometric perspective. National Accounts data are modified in order to take explicitly into account the capital services provided by public capital, especially when the endogenous approach to the internal rate of return determination is adopted. Accordingly, *GVA* figures provided by *NA* are underestimated by 5%-6% while Gross Operating Surplus is also underestimated by around 15%. The share of capital services on total output is also affected, being around 3.5 percentage points higher in the revised approach than in the standard one. However, the growth rates of both, *GVA* and that of the Volume Index of Capital Services, are not significantly affected. Under some restrictive assumptions (constant returns to scale, perfectly competitive markets and optimizing behaviour) we are able to calculate the output elasticities of the different types of assets. Computed infrastructures elasticities are similar to those obtained from previous econometric estimates in a range of around 0.06. By contrast, according to our estimates, we find slightly increasing infrastructures elasticities while previous results indicated the opposite trend.

It is interesting to notice that neither ICT elasticities nor the aggregate rate of growth of these types of assets are practically affected by the use of any of the two approaches. As a consequence, their contribution to the growth rate of labour productivity does not seem to depend on the chosen methodology. Additionally, the growth accounting exercise carried out indicates that *ICT* contribution to Spanish productivity growth has been higher than infrastructures in both subperiods, 1995-2000 and 2000-2004, even though its share in output has been lower. However, *ICT* capital deepening contribution slowed down in 2000-2004 compared to 1995-2000 in a general context of recovery of i) labor productivity; *ii*) capital deepening of the remaining forms of capital (including infrastructures); and *iii*) less negative *TFP* contribution.

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NOTES

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[1] Spain was not an exception and an important amount of papers dealing with the subject can be traced (see Mas & Maudos (2004) for details).

[2] Bailey (2003), Bailey & Gordon (1998), Gordon (1999), Jorgenson & Stiroh (2000), Oliner & Sichel (2000) and Stiroh (2002) among others.

[3] Colechia & Schreyer (2001), O´Mahony & van Ark (2003), Pilat (2003), van Ark & Timmer (2006) and Timmer & van Ark (2005).

[4] Equation [5] assumes that the user cost for each particular type of asset is the same across industries. This assumption could be inadequate if the level of risk is different between industries –as most probably it is the case. It should be anticipated that the expected return on an asset that it is owned and used in a risky industry should be higher than the expected return if the same asset is used in a low-risk industry. I thank P. Schreyer for driving my attention to this important point.

[5] This assumption is also very useful since it prevents that changes in the organization of the public sector affect the performance of the economy. For instance, when the provision of capital services previously provided by the public sector (according to *NA*) it is now supplied by a public entity (now considered by *NA* similar to a private enterprise).

[6] The details can be found in Mas, Pérez and Uriel (2005, 2006).

[7] For the purpose of this exercise the information has been updated to 2004 on a provisional basis.

[8] The public sector corresponds exactly with *NA* definition. That is to say, total public Gross Fixed Capital Formation figures in the Spanish capital services estimates are taken directly from *NA*.

[9] The above procedure has a limitation, originated by the lack of sufficiently detailed information. This constraint deals with the one-to-one correspondence between assets and industries. A more realistic view would take into account that a given industry, lets say *Airport,* uses different types of assets coming from 16. *other constructions n.e.c,* 17. *software,* 8. *other transport equipment,* and so on. We are presently working on this important issue, but no definitive results are available yet.

[10] Mas (2005) addresses similar issues but including residential capital, and thus rents, in the calculations.

[11] Corrado, Hulten and Sichel (2006) perform a somehow similar exercise but related to intangible capital

[12] Remember that, according to equation [10] the user cost expression has two elements: the price of the asset, $p_{j,t}$, and the user cost per euro invested: $(\beta_t i_t + (1 - \beta_t) \rho_t - \pi_{j,t} + (1+\pi_{j,t}) \delta_{j,t})$.

[13] Of course, in the case of individual assets, such as the three *ICT* assets the difference is zero.

[14] We are not considering explicitly labor quality in order to concentrate in infrastructures and *ICT*. Therefore its contribution to growth is embedded in the residual term. Mas & Quesada (2005, 2006) include the human capital term in their growth accounting results.

[15] Further details can be found in Mas & Quesada (2005a,b & 2006)