THE CONTRIBUTION OF ICT TO ECONOMIC ACTIVITY: A GROWTH ACCOUNTING EXERCISE WITH SPANISH FIRM-LEVEL DATA

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Abstract

This paper uses a well-established growth accounting framework to measure the contribution of ICT goods (considered as capital inputs) to output and labour productivity growth in the Spanish economy. We apply this framework to a sample of around 1300 Spanish firms per year over the period 1991-2000. The use of micro-level data is especially useful for the purpose in hand. Firstly, our database provides detailed breakdowns of capital. This helps mitigate the usual mismeasurement problems in obtaining capital stocks. Secondly, by avoiding the usual availability lags associated with the use of aggregate data, we can focus on a more recent period. The main findings may be summarised as follows. 1) The use of ICT as a capital input has made a positive and, relative to its cost share, significant contribution to output and productivity growth. 2) This contribution was higher in the second half of the 1990s. For this period, we estimate that the use of ICT inputs accounted for nearly one-fourth of labour productivity growth. 3) At a sectoral level, we find that there is a general rise in the share of ICT in total capital and a general reduction in ICT cost shares, driven by the sharp downward trend in the prices of ICT products. However, the contribution of ICT inputs displays a degree of heterogeneity across sectors, owing to the disparity of sectoral accumulation rates of ICT inputs. Finally, results at the firm level exhibit a notable heterogeneity, although a majority of firms have experienced an increase in the ICT capital growth rates and in the ICT contribution to growth.

JEL categories: O33, D24, L63

Keywords: Information and Communication Technologies, Growth Accounting, Technological Change.

1. Introduction

Over the last decade, there has been enormous technical progress in the information and communication technologies (ICT) industries. These efficiency gains have driven down the relative prices of computers, software and communications equipment and have significantly stimulated the demand for this type of good. As a consequence, the ICT- producing industries have experienced, at least in some economies, unprecedented growth rates and have contributed to the acceleration of total factor productivity growth. Furthermore, the impact of technical advances in ICT on economic activity goes beyond the direct impact on ICT-producing industries. A potentially strong impact stems from the adoption and use of new technologies in most sectors of the economy. In this respect, the reduction in the prices of ICT capital goods encourages the accumulation of this type of input. Consequently, the diffusion of ICT as a capital input might have contributed significantly to output and labour productivity growth. Finally, an additional contribution of ICT to growth may arise from an acceleration of TFP growth due to efficiency enhancing effects arising from the production and adoption of ICT.

However, the empirical assessment of the role of ICT in economic activity poses considerable statistical problems. Firstly, the relevant information is not available on a timely basis (in the Spanish case, sectoral information is available only with a four-year lag). Secondly, detailed breakdowns of capital and investment are not usually accessible. Thirdly, significant measurement problems arise from the difficulty of constructing adequate price indices and of calculating economic depreciation for ICT capital goods. Given these data limitations, the use of firm-level data, though they do not solve all measurement problems, represents a promising avenue, and it is that which we explore in this paper.

Our objective is to examine the relationship between the use of ICT as a capital input and the recent performance of productivity growth in Spain. Therefore, rather than analysing the contribution of ICT-producing industries to economic development we adopt an input-oriented approach that focuses on the role of ICT as a capital input in all sectors of the economy. For this purpose, we estimate, using a standard growth accounting framework, the contributions to output and productivity growth from the use of the different inputs (ICT among them). This analytical framework has already been used to estimate, with aggregate information, the growth contribution from the use of ICT capital in the U.S. and other industrialised economies -Oliner and Sichel (2000), Schreyer (2000), Colecchia and Schreyer (2001) and Daveri (2001)-.[1] In this paper, we conduct the analysis using firm-level data. More precisely, we make use of a sample of Spanish firms over the period 1991-2000, obtained from the Central Balance Sheet Office of the Bank of Spain. The final sample includes about 1300 firms per year and it provides information for sufficiently detailed breakdowns of capital.

By conducting the analysis at the firm level, we reduce difficulties arising from mismeasurement of capital stocks. As potential additional advantages, the use of individual data

[1] Most of the estimates of the contribution of ICT inputs to output growth concern the US economy. Additional references are Jorgenson and Stiroh (2000) and Whelan (1999).

would allow the distinctive features of the financial structure of technology-intensive firms to be identified and offers some pointers to the factors influencing the effect of ICT capital on productivity growth. Nevertheless, the individual data also entail some problems. Thus, capital stock figures have to be converted from book value to market value. Next, sample coverage, in terms of value added and employment is, for a few sectors, low. Further, the sample we use is definitely biased towards large firms. Finally, our sample does not enable us to consider labour quality as a contributing factor to growth. Given these drawbacks, our results should be viewed with some caution.

Although we use individual firm data, our main objective is to derive some general conclusions about the ICT contribution to growth for the whole non-financial market economy. For this purpose, we first obtain sectoral figures (we consider 17 sectors) by averaging firms' behaviour by sector. Thus, we implicitly assume that the average performance of the firms in the sample is representative of the sector they belong to. We then obtain aggregate figures by averaging sectoral results, weighting them by their share in the whole market economy. We check that our conclusion about the ICT contribution to growth for the aggregate economy is robust to alternative procedures of aggregation of the individual ICT contributions.

Our results suggest that the ICT contribution to growth and ICT capital accumulation rates have been relatively significant although quantitatively smaller than in the US. Thus, according to Oliner and Sichel (2000), over the period 1996–1999, ICT capital deepening explained almost one-quarter of each percentage point of US output growth, while this figure was around 0.10 p.p. for the Spanish case in the second half of the nineties (1996-2000). Over the period 1996-1999, these authors report US annual growth rates for hardware and software of about 21% and 13%, respectively. The corresponding growth rates for the Spanish economy were 12% and 9%, respectively. These growth rates can be considered as low if we take into account that there is a most sizeable gap between US and Spain in terms of ICT capital deepening.

To our knowledge, for the Spanish case, only Daveri (2001) has analysed the growth impact of ICT accumulation within a growth accounting framework. Compared with our findings, Daveri reports a similar ICT contribution for the whole period considered but a lower one for the second half of the nineties.[2] Nevertheless, there are some substantial differences between Daveri's study and the one presented here. First, Daveri assumes perfect competition, computing the contribution to growth of factor inputs in terms of income shares, while we relax this assumption and, therefore, compute these contributions in terms of cost shares. Second, he uses aggregate data from a very different data set (ICT expenditure taken from WITSA/IDC and National Accounts OECD series).

[2] Thus, for the period 1991-1999, Daveri reports an annual ICT contribution to output growth of 0.36 p.p.. In this paper the corresponding figure is 0.35 p.p.. However, for the period 1996-1999 Daveri finds an ICT contribution of 0.34 p.p., meanwhile we find a corresponding figure of 0.42 p.p..

The rest of the paper is organised as follows. Section 2 describes the analytical framework. Section 3 introduces our database paying special attention to the description of the price indices for capital inputs and to the construction of the capital stocks and the user costs of the capital inputs. A more detailed description of the sample and the definition of variables are relegated to Annex 1. Section 4 presents the results for the whole economy, as well as for the 17 sectors considered. Finally, section 5 concludes.

2. The analytical framework: Neoclassical growth accounting

In this paper we apply the neo-classical growth accounting framework developed originally by Solow (1957). This framework has been extensively applied in other studies on the ICT contribution to growth, such as Oliner and Sichel (2000), Jorgenson and Stiroh (2000), Schreyer (2000), Daveri (2000), among others. Our main departures from these authors are twofold. First, we use individual firm data, and, second, following Hall (1990), we do not impose perfect competition.[3]

We start from a Cobb-Douglas production function (*F*) that relates firm value-added (*Q*) to seven inputs: labour (*L*), software (K_{sw}), hardware (K_{hw}), non-residential buildings (K_{bld}), industrial equipment (K_{ieq}), other equipment and furniture (K_{oeq}) and transportation equipment (K_{trp}).[4] Thus:

$$Q = q\ F(L, K_{sw}, K_{hw}, K_{bld}, K_{ieq}, K_{oeq}, K_{trp})$$

where we assume that *F* displays constant returns to scale in factor inputs.

Computing growth rates:

$$\Delta q = \Delta q + \frac{L}{Q}\frac{\partial F}{\partial L}\Delta l + \sum_i \frac{K_i}{Q}\frac{\partial F}{\partial K_i}\Delta k_i \qquad (1)$$

i = sw, hw, bld, ieq, oeq, trp

where lower case letters correspond to the logarithms of the corresponding upper-case variables. The term *q* captures output growth not accounted for by changes in factor inputs, and approximates total multifactor productivity (TFP).

First order conditions for cost minimization are:

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[3] Given that we use individual data on a yearly basis, we consider this strategy more appropriate.

[4] These are the breakdowns of capital that are available in our database. McGuckin and Stiroh (2002) highlight the importance of using a detailed breakdown of capital in order to avoid the important biases in the measurement of the productive impact of the different inputs that arise when the elasticity of all types of non-computer capital is incorrectly restricted to be equal.

$$\frac{\partial F}{\partial K_i} = \frac{r_i}{mc} \quad \text{and} \quad \frac{\partial F}{\partial L} = \frac{w}{mc} \tag{2}$$

where r_i *is the rental price of* capital *i* and *w* is the labour market wage. Given that, with constant returns, marginal cost (*mc)* is equal to average cost at the cost minimization value of inputs, we can write:

$$\frac{\partial F}{\partial L} = \frac{w\,Q}{wL + \sum r_i\ k_i} \tag{3}$$

and

$$\frac{\partial F}{\partial K_i} = \frac{r_i\ Q}{wL + \sum r_i\ k_i} \tag{4}$$

Some simple algebra leads to:

$$\frac{\partial F}{\partial L} = \frac{w\ L}{wL + \sum r_i\ k_i}\ \frac{Q}{L} = a_L\ \frac{Q}{L} \tag{5}$$

$$\frac{\partial F}{\partial K_i} = \frac{r_i\ K_i}{wL + \sum r_i\ k_i}\ \frac{Q}{K_i} = a_{K_i}\ \frac{Q}{K_i} \tag{6}$$

where a_i is the cost share of input *i*. Substituting (5) and (6) in (1):

$$\Delta q = \sum_i a_{k_i}\ \Delta k_i\ + a_L\ \Delta l + \Delta TFP \tag{7}$$

Thus, in equation (7), each input's contribution is obtained by multiplying its rate of change by each factor's share in total cost (a_i).[5] Additionally, in the computation of the cost shares, we introduce the assumption that all types of capital earn the same competitive rate of return at the margin, net of depreciation and capital gains or losses implied by the changes in the prices of capital goods. Thus, we are assuming that firms allocate resources efficiently. To impose the same rate of return for all capital assets implies a very high gross rate of return for ICT to offset the rapid depreciation and the capital losses arising from the decline in ICT prices.

Grouping terms in equation (7) yields:

[5] An alternative approach would be to estimate the parameters of the production function. Although such an approach does not require the introduction of the neo-classical assumptions, it requires assuming the homogeneity of the parameters of the production function, at least, across sectors.

$$\Delta q = c_l + c_{ITC} + c_{OTHERK} + \Delta TFP \qquad (8)$$

where c_l is the contribution of the labour input to value added growth, c_{ICT} is the contribution of ICT capital and $c_{OTHER\,K}$ is the contribution of non-ICT capital, being:

$$c_l = a_l \ \Delta l \qquad (9)$$

$$c_{ITC} = a_{sw} \Delta k_{sw} + a_{hw} \Delta k_{hw} \qquad (10)$$

$$c_{OTHERK} = a_{bld} \Delta k_{bld} + a_{ieq} \Delta k_{ieq} + a_{oeq} \Delta k_{oeq} + a_{trp} \Delta k_{trp} \qquad (11)$$

Alternatively, by rearranging equation (7) we can obtain a similar decomposition for labour productivity growth:

$$\Delta q - \Delta l = cl_{ITC} + cl_{OTHERK} + \Delta TFP \qquad (12)$$

where

$$cl_{ITC} = a_{sw} (\Delta k_{sw} - \Delta l) + a_{hw} (\Delta k_{hw} - \Delta l) \qquad (13)$$

$$cl_{OTHERK} = a_{bld} (\Delta k_{bld} - \Delta l) + a_{ieq} (\Delta k_{ieq} - \Delta l) + a_{oeq} (\Delta k_{oeq} - \Delta l) + a_{trp} (\Delta k_{trp} - \Delta l) \qquad (14)$$

According to this expression, growth in labour productivity is explained by the intensity of the process of capital deepening (increase in the amount of capital per unit of labour) and by the growth rate of TFP.

The neoclassical growth accounting framework provides a simple analysis of the proximate sources of economic growth. It decomposes the growth rate of output into the sum of two factors: the rate of increase of inputs and the multifactor productivity growth. Thus, this framework represents a limited approach to understanding the process of economic growth. It does not adequately explain which are the underlying factors driving the substitution processes between factors or which are the causes behind the growth of TFP.

In our case, we calculate each component of equations (8) and (12) (that is, the value added growth rate, factor input contributions and the TFP growth rate) for each firm in the sample. To obtain the components of equations (8) and (12) for the total non-financial market economy from the components computed at the firm level we take two additional steps.

First, we average these components by sector. For the sake of robustness, in this step, we consider two alternative sectoral breakdowns (the National Accounts sectoral breakdown into 71 industries and the breakdown into 17 sectors used in Estrada and López-Salido(2001)[6]) and we use two methods of aggregation: a) we compute the sectoral contributions as simple averages of the individual ones, and b) we add up the individual data for value added and productive inputs and then obtain the sectoral contributions.[7]

Second, we obtain the figures for the total non-financial market economy by taking the average of the sectors for each component, the sectors being weighted by their share in total value added. Sectoral weights are calculated using data taken from Estrada and López-Salido (2001) in the case of the 17-sector breakdown and are directly taken from the National Accounts in the case of the 71-sector breakdown.[8]

3. The data

From the previous section, the contribution of each type of capital to output growth depends on its cost share and on its accumulation rate. Therefore, the validity of this exercise depends on the accurate measurement of two elements: the capital stocks and their user costs. Before describing the method of construction of these two elements, we discuss our choice of price indices for capital inputs as these are an essential component in the computation of both the capital stocks and the user costs.

Price indices for capital inputs.

The choice of an appropriate deflator for capital inputs is crucial both for the measurement of the capital stocks and for the computation of the user costs. This task is particularly delicate in the case of ICT capital goods. Most of these ICT capital goods have undergone significant quality changes that if not properly taken into account will lead to an overestimation of the price change in ICT capital goods and to an underestimation of the corresponding capital stocks. Therefore, the use of price indices for ICT capital goods based on the application of "hedonic" techniques seems to be an essential tool to decompose the change in the nominal capital stocks into their price and quantity components.

Given that, for the Spanish economy, there is no price index for ICT goods in constant quality terms[9], we apply an indirect approach –based on Schreyer (2000)- to obtain an adequate ICT deflator. Schreyer constructs the ICT price deflator for a given country in such a way that the difference between the ICT price change and the price change in all other investment goods for that country is equal to the difference between the same price changes for the US economy.

[6] Estrada and López-Salido (2001) construct a database on a yearly basis, using National Accounts, with information on several economic variables for 17 sectors, excluding the non-market economy and financial sector, for the period 1980-1999. The use of this breakdown of the market economy into 17 sectors was determined by the availability of this database.

[7] In Annex 2 we discuss the choice of the aggregation method and we present the results for the alternative procedures of aggregation of the information computed at the individual level.

[8] In the case of the 71-sector breakdown, since sectoral data from National Accounts (ESA 95) is only available for the period 1995-1997, we use 1995 weights for period 1992-1995 and 1997 weights for the period 1996-2000. In order to obtain annual variation for these weights, we have corrected them with the weights for the 17 sectors considered in Estrada and López-Salido (2001).

[9] Izquierdo and Matea (2001) provide a series of hedonic prices for personal computers in Spain. We have not used this series because personal computers are just one product among those included in our hardware category.

We closely follow Schreyer's methodology and compute the price deflator for capital input i (P_i) by assuming that the ratio of the deflator of capital input i to the GDP deflator in Spain is the same as the corresponding ratio in the US. We have applied this procedure for deflation to ICT capital inputs: hardware and software

To test the sensitivity of the results to the choice of deflator for the ICT capital inputs we have alternatively used a set of price indices for these inputs taken directly from Spanish official statistical sources. Figure 1 displays the time profile of the deflators for the capital inputs and, in particular, it provides a comparison between the two sets of deflators for the ICT inputs.[10] In the case of hardware, the index computed using US deflators shows a significantly more pronounced decline. This result clearly shows to what extent not taking into account the quality changes in these ICT goods introduces a serious bias in the estimation of their price changes. Using Spanish statistical sources, we are unable to obtain a deflator for software. As this figure makes clear, using a common deflator for hardware and software is highly misleading.

Capital stocks

Our database provides accounting data corresponding to the six types of capital assets already mentioned: software (K_{sw}), hardware (K_{hw}), non-residential buildings (K_{bld}), industrial equipment (K_{ieq}), other equipment and furniture (K_{oeq}) and transportation equipment (K_{trp}). It should be mentioned that in our sample, software capital comprises successful R+D investment, and hardware capital includes communications equipment. In this paper we construct measures of the capital stocks using this accounting information. More precisely, we have information on the net book value (at historic prices) of the six types of capital and we can construct the average age of each capital item (as the two-year average of the ratio of total accumulated depreciation to current depreciation). Using the price indices for investment goods already described, the book values of the capital stocks and their average ages we can obtain the value of the capital stocks at constant and current prices.[11] We apply this procedure to all the observations for each firm. An alternative approach to this procedure would be the perpetual inventory method, which combines the information on the capital stock at constant prices in an initial year with information on investment volumes for the subsequent years.[12]

As already mentioned, the availability of micro-level information has undeniable advantages for the purpose of this paper. However, the use of accounting data to obtain measures of capital stocks also has some limitations. In particular, given that the available information is on the book value (net of economic depreciation) of fixed capital we are constrained to construct wealth measures of the capital stocks, i.e, measures of the market value of the assets of the firm. However, as is thoroughly discussed in Oliner and Sichel (2000) and Schreyer (2000), the relevant measure of capital inputs for a growth accounting exercise is

[10] See Annex 1 for the detailed definition of both sets of price deflators.

[11] We essentially apply the same methodology as in Hall (1990). Further details on the computation of the capital stocks are given in Annex 1.

[12] Unfortunately, the lack of sufficiently detailed breakdowns of investment prevents us from adopting this standard approach in the construction of capital stocks.

that provided by the productive stocks of the inputs, that is, the productive capacity of the stock. In other words, the productive stocks take into account the physical decay of the assets whereas the wealth stocks reflect the economic depreciation. For most of the capital assets, these concepts are related but this is not the case for computers. Computers experience very little physical decay but they suffer a very high economic depreciation (as they have a very short life-cycle). As we are constrained to use a wealth measure for the capital stocks, our estimates of the growth contributions of ICT capital assets (for which the difference between the productive and the wealth stock is relevant) will be biased downwards.

Figure 2 shows the growth rates of the ICT (types K_{sw} and K_{hw}) capital stocks at constant prices and the changes in the ratio of ICT capital to total capital. Both these ICT capital goods have experienced outstanding growth rates (much higher than those for non-ICT capital). As a consequence, the share of ICT capital goods in the total capital stock has steadily increased over the period considered and this accumulation process has substantially accelerated in the second half of the decade. Thus, the weight of ICT capital in the total capital stock was almost 11% in 2000, twice the corresponding figure for 1992 (5.2%). This process has been similarly intense for software (its weight in the total capital stock has risen from 1.5% to 3.1%) and for hardware (from 3.7% to 7.8%). These figures suggest that a strong process of substitution of ICT capital for other types of capital input has taken place, mainly driven by the sharp downward trend in the prices of ICT inputs.

Cost shares

Each factor's cost share is defined as the ratio of the cost of the input to total cost of output which, under the neoclassical assumptions, is equal to total costs. In the case of labour, its cost can be directly obtained from the accounting data. In the case of the capital inputs, its computation –given by the product of the capital stock and its rental price or user cost- is not so straightforward.

The definition of the user cost of the capital input K_i is given by the product of three terms: the acquisition price (P_i), the gross rate of return (R_i) and a fiscal correction factor (f).

$$UC_i = P_i R_i f$$

In what follows, we focus on the computation of the gross rate of return. The acquisition price has been previously discussed and the fiscal correction factor, which is constructed at a sectoral level, is described in more detail in Annex 1. This fiscal correction factor, which is assumed to be common to all types of capital, reflects taxes and fiscal incentives.

The gross rate of return for capital input K_i is given by the following expression:

$$R_i = r + d_i - p_i$$

where r is the net rate of return common to all types of capital (representing the opportunity cost of the investment)[13], d_i is the depreciation rate (which proxies the loss in market value due to ageing) and p_i is the capital price inflation (reflecting capital gains or losses).

Two factors determine the evolution of the cost share of each capital input: its user cost and its weight in total capital. Figure 3 displays the path, in real terms[14], of the first of these factors, the rental price or user cost, for all the types of capital inputs considered. Given that the depreciation rates and the fiscal correction factor have remained quite stable over the sample period, the time profile is mostly explained by the capital price inflation and by the opportunity cost of investment. Provided that this last factor is assumed to be common to all types of capital, the price changes in capital goods is left as the main cause explaining differences in the changes in the cost shares across types of capital. Especially remarkable is the fall in the user costs of ICT capital, particularly hardware, relative to the user costs of other types of capital input. This relative behaviour of user costs is decisive in explaining the existence of strong substitution effects between different types of capital.

As Figure 4 shows, there has been a markedly different time profile for the cost shares of ICT and non-ICT capital inputs. On the one hand, in the case of non-ICT capital inputs, their cost share has shown a significant downward trend throughout the sample period, mainly driven by the declining weight of non-ICT capital in total fixed capital. On the other hand, the cost share of ICT capital goods has exhibited a slight downward trend which is the result of two effects of large magnitude but opposite sign: the increasing weight of ICT capital inputs and the sharp decline in their rental price. This declining trend in the cost share of total ICT capital is mostly explained by the behaviour of the cost share of hardware. However, in the case of software, the decline in its rental price has not been so sharp as to cancel out the increase in its weight in total fixed capital. Thus, we observe a slightly growing cost share for software.

4. Growth contribution from the use of ICT as a capital input

Once the information on the rates of growth of different inputs and their costs shares is available, using equations (8) and (12) we can straightforwardly approximate the decomposition of output and labour productivity growth. Given that our analysis is performed at the firm level, we report three types of results. First, we provide a decomposition of output growth for the whole market economy. As already mentioned, we compute this decomposition in three steps. In the first step, we compute each element of equations (8) and (12) at the individual level. Next, by taking sectoral averages for each of these components, we obtain a decomposition of output

[13] In the construction of the net rate of return r, which has been assumed to be common for all firms within the same sector, we have not taken into account the composition of financing.

[14] That is $\left(r+d_i-p_i\right)\frac{P_{it}K_{it}}{P_{i95}K_{it}}$, where $P_{it}K_{it}$ is capital input i, in nominal terms, and $P_{i95}K_{it}$ is capital input i at constant prices.

growth at the sectoral level.[15] Then, using value-added weights, we aggregate these sectoral results. Second, we provide a discussion of the results at the sectoral level. Finally, we report the distribution of individual ICT capital contributions to growth.

4.1. AGGREGATED MARKET ECONOMY RESULTS

Table 1 presents the decomposition of output growth. The first column reports the results for the overall period, 1992-2000. During these years, value-added for the non-financial market economy rose at an annual average rate of 2.9%. The contribution of ICT capital (line 5) represented 0.38 percentage points, of which 0.16 was explained by computer software and 0.22 by hardware. Therefore, the ICT contribution to growth was small during the 90s, being around half of the contribution accounted for by other fixed capital. Nevertheless several comments should be made.

First, over the period under study, the ICT capital stock increased at an annual average rate of 7.5%, while non-ICT capital rose at a rate of 0.9%. Consequently, the contribution of ICT capital to growth was moderate because ICT capital still represents a very modest fraction of total capital stock (7.6%) and so, its share in total cost is rather small (2.0%). In other words, relative to its share in either total cost or in the total fixed capital stock, the contribution of ICT capital to growth has been considerable (see lines 26 and 30 of Table 1).

Second, throughout the analysed period, the ICT contribution has been increasing (see columns 2 and 3 of Table 1). Thus, for the period 1996-2000, the ICT contribution to annual value-added growth reached 0.45 percentage points, 55% higher than the average contribution for the period 1992-1995. Conversely, non-ICT capital contribution has significantly decreased.

Third, the rise in the ICT contribution to growth during the second half of the 90s is explained by an acceleration in ICT accumulation rates, since the ICT cost share declined slightly between these two periods. Thus, annual growth rates for new technology equipment rose from 4.4% during 1992-1995 to 10.1% during 1996-2000. Given these growth rates, which were also considerable in nominal terms, the reduction in the ICT cost share is explained, as already mentioned, by the exceptional decline in ICT capital goods prices.

Finally, it should be mentioned that there are some differences between the contributions of computer software and hardware to growth. Thus, while the contribution of computer software to growth rose significantly between 1992-1995 and 1996-2000, the contribution of computer hardware increased moderately. Nevertheless, the growth rate of computer hardware accelerated considerably more than that of computer software. In spite of

[15] As already mentioned, in this step we have considered two alternative sectoral breakdowns and we have computed both simple and weighted averages. In what follows, we present the results corresponding to the case of the 17-sectors breakdown and where the sectoral figures are computed as simple averages of the individual ones. This aggregation method is the one that best approximates the growth rates observed for several economic variables with National Accounts data. Nevertheless, the results are robust to the alternative procedures of aggregation (see Annex 2 for detailed results).

that, the sharp decline in user costs of computer hardware explains the moderate increase of its contribution to output growth.

Table 2 presents a decomposition of labour productivity growth. For the overall period, labour productivity grew at an average annual rate of 2.22%. The process of ICT capital deepening showed an average contribution to productivity growth of 0.35 percentage points. Furthermore, this contribution surged in the second half of the 90's, when the average annual ICT contribution reached 0.38 percentage points, up from 0.31 in the period 1992-1995. In relative terms, this increase in the ICT contribution is even sharper. Thus, while in the period 1992-1995 the ICT contribution explained, on average, 0.11 of each percentage point of labour productivity growth, this figure was 0.23 in the period 1996-2000. By contrast, the contribution of non-ICT capital to labour productivity growth declined over the period considered. These results suggest then that the slowdown in labour productivity growth during the second half of the 90s was mostly explained by a reduction in non-ICT capital deepening growth rate, since the slowdown in TFP growth was not as sharp as that in labour productivity growth.

4.2. SECTORAL RESULTS

Table 3 shows the sectoral breakdown we have considered, together with each sector's share in value-added, the number of observations in the sample, its coverage (in terms of value added and employment) and the number of firms in the sample for which the ICT capital stock is zero. For most sectors, sample coverage can be considered as relatively high, although for six of them it is lower than 15% (in terms of value added), and, therefore, results for these sectors should be viewed with more caution.

Figure 5 presents sectoral ICT cost shares, ICT shares in total fixed capital, ICT capital growth rates and the contribution of ICT capital to growth. These sectoral variables have been computed by averaging firm values within the sector. Therefore, the results presented here correspond to the average firm behaviour in the sample, and we take them to be representative of the corresponding sector. The results at the industry level can be summarised as follows:

First, all sectors, except *Other Market Services*[16], display a small ICT capital share in total fixed capital (see panel 1 of Figure 5), ranging from 2.2% (for *Rubber and Plastic products*) to 8.1% (*Communication Services*). Consequently, cost shares are also small. However, throughout the period considered, all sectors experienced a significant ICT capital growth rate, contrasting with that for non-ICT capital (see panel 3). Given the modest fraction of new technology capital, the average ICT contribution to output growth was small, ranging from 0.15 percentage points for *Building and Construction* to 1.4 p.p. for *Communication Services*. However, for all sectors this contribution was been, relative to cost shares, much higher than that of the non-ICT capital stock (see panel 4).

[16] *Other Market Services*, which include real estate, business services and computer services activities, presents an average ICT capital share of 15.5%, far above that in the other sectors.

Second, all sectors have experienced a rise in the share of ICT capital in total fixed capital throughout the period considered. In most sectors, this substitution of ICT capital for non-ICT capital, explained by relative price developments, have accelerated in the second half of the period considered. Thus, for 15 sectors, annual ICT growth rates were higher during 1996-2000 than during 1992-1995 (see panel 7 of Figure 5), this acceleration being especially remarkable for Communication Services and Other Market Services. In spite of these accumulation rates, cost shares have been lower in the second half of the analysed period for most sectors (13 of them), reflecting the significant decline experienced in ICT capital good prices (see panel 6).

Third, for most sectors (13 of them), the ICT growth rate acceleration outweighted the decline in the cost share, and, consequently, the ICT contribution to output growth increased in 1996-2000 relative to 1992-1995 (see panel 8). However, in terms of labour productivity growth, only 9 sectors experienced a higher ICT contribution in the second half of the 90s (see panel 9)[17], despite the general rise in ICT capital deepening[18].

In sum, although the ICT contribution to growth across sectors displays a degree of heterogeneity, most sectors show similar main results to those for the whole market economy. That is, the ICT contribution to growth is small in absolute terms, but it was increasing over the period covered. This increase is mostly explained by an acceleration in ICT capital accumulation.

ICT contribution to growth in ICT-producing sectors

It is often argued that the dramatic price decline in ICT capital goods over recent decades can be explained by the efficiency gains in the ICT-producing sectors. Therefore, it seems worth analysing growth developments, in terms of output and productivity, in those sectors producing goods and services related to ICT[19].

We have considered three ICT producing sectors: *ICT manufacturing*, which comprises the production of ICT goods, *ICT Communications* and *ICT Computer Services*[20]. It should be pointed out that we do not have value-added deflators with the required level of disaggregation. Therefore value-added, labour productivity and TFP are, probably, imperfectly measured. Results for the analysis performed are presented in Figure 6. ICT-producing sectors have experienced higher ICT capital growth rates and higher ICT contributions to value-added growth than other economic sectors. This is especially the case for the second half of the sample period.

Value-added growth rates in these sectors have been significantly higher than those for the rest of the economy. Therefore, ICT-producing sectors have contributed positively to output

[17] Nevertheless, relative to labour productivity growth, the ICT contribution increased in 11 of the 17 sectors.

[18] The ICT capital labour ratio rose in 16 of the 17 sectors.

[19] For a more detailed study of ICT-producing sectors see Nuñez (2001).

[20] More specifically, using NACE/93, *ICT manufacturing* includes divisions 30 and 31 and groups 313, 332 and 333, *ICT Communications* group 641 and *ICT computer services* corresponds to division 72.

growth, although given the modest share of ICT value-added in total economy (around 5.2%), this contribution has been small. In terms of total factor productivity, *ICT manufacturing* and *ICT Communications* have experienced much higher growth rates than other sectors. Besides, these growth rates have accelerated in the second half of the sample period, in contrast to the slowdown in TFP growth in the whole market economy.

Table 4 reports the contribution of ICT industries to total market economy TFP growth[21]. For the period 1992-1995, this contribution was, in annual average terms, 0.17 p.p., rising to 0.19 p.p. in the period1996-2000. Relative to total economy TFP growth, these contributions were 14% and 19%, respectively, which can be considered high if we take into account that ICT producing sectors account for only 5% of total value added. More importantly, these high relative contributions imply that the other branches of activity, with a much higher weight, have recorded a very low and declining rate of TFP growth. These results might suggest therefore that the use of ICT has not, as yet, given rise to positive spillover effects that have translated into increases in productive efficiency for the whole economy, or, if there have been any, they have not been able to offset the negative effect of other determinants of total productivity.

4.3 CROSS-SECTIONAL DISTRIBUTION OF ICT CONTRIBUTIONS TO VALUE ADDED GROWTH

In this section we try to provide an overview of the results obtained at the individual level. For this purpose, Figure 7 displays the cross-sectional distributions of ICT contributions to value-added growth and of their two main determinants, the ICT cost shares and the ICT accumulation rates. These distributions are presented both for the 1992-1995 and 1996-2000 periods. As was already clear from the sectoral results, the average decomposition of output growth hides very heterogeneous individual behaviours. Panel 1 of Figure 7 shows that the distribution of ICT contributions to output growth is highly skewed to the left. Whereas the average ICT contribution to output growth was nearly 0.40 percentage points (see Table 1), around 75% of the firms exhibit an ICT contribution below this average value. And this contribution is even negative for a significant fraction of firms. As can be seen from Panel 2, these negative contributions are driven by the presence of negative accumulation rates. In most cases, these negative accumulation rates arise from the fact that the gross ICT investment is not enough to offset the high depreciation rates of the installed ICT capital. Only in a small number of cases are sales of ICT capital goods observed. The cross-sectional distribution of ICT cost shares is again extremely skewed to the left (see Panel 3). Almost 80% of the firms have ICT cost shares below the average ICT cost share (2.0% for the whole period). It is also noteworthy that the fraction of firms with a zero ICT cost share is very low (around 5% of the sample).

Finally, it is interesting to analyse how these distributions have evolved over the sample period. Comparing the periods 1992-1995 and 1996-2000, the rise in the average ICT contribution from 0.29 to 0.45 percentage points (see Table 1) is also reflected in a slight shift to the right in the distribution of ICT contributions. This shift is especially visible in the lower tail of

[21] This contribution is computed as the product of TFP growth in ICT industries and the value added weight of ICT industries (see Schreyer, 2001).

the distribution with the reduction in the percentage of firms with negative contributions. Thus, the percentage of firms with a negative ICT contribution decreases from 33% in the early nineties to 24% in the second half of the sample period. Nevertheless, the changes, of opposite sign, in accumulation rates and prices of ICT goods explain the notable stability of this distribution. Thus, the small change in the distribution of ICT contributions is mostly driven by the significant shift to the right in the distribution of ICT accumulation rates that offset the shift to the left in the distribution of ICT cost shares. Again, this shift is more perceptible in the lower tail of the distribution. For example, the percentage of firms with an ICT cost share below 1% rises from 51% in the first half of the decade to 60% in the late nineties.

5. Conclusions

This paper examines the role played by ICT capital as an input factor and, more specifically, as a factor contributing to output growth in the Spanish Economy in the period 1992-2000. For this purpose, we use a standard growth accounting framework and a firm-level database. In order to obtain a general conclusion regarding the ICT contribution to growth for the whole non-financial market economy, we aggregate the individual results in two steps. First, we obtain sectoral figures by averaging firms' results by sector. Thus, we implicitly assume that the average performance of the firms in the sample is representative of the sector they belong to. We then obtain aggregate figures by averaging sectoral results, weighting them by their share in the whole market economy.

The use of firm-level data is helpful to overcome some difficulties associated with the use of aggregate data, mainly the availability lags and the mismeasurement of capital stocks. However, individual data also pose some problems for the purpose in hand. In particular, the uneven coverage of the sample, both by sector and by size of firm, and the need to transform accounting data into information that is meaningful in economic terms, represent important limitations. Bearing in mind these drawbacks, our results should be viewed with some caution.

Our main findings may be summarised as follows. First, the use of ICT as a capital input has made a positive and, relative to its cost share, important contribution to output and productivity growth. Over the whole sample period considered, the contribution of ICT equipment amounts to about one-third of the entire contribution of fixed capital to both output and labour productivity growth. This is especially noteworthy if we take into account that the cost share for ICT capital inputs represents around one-tenth of the cost share for the total fixed capital. Second, this contribution has been higher in the second half of the 1990s, in spite of the slight decrease in the cost share of ICT capital goods. For this period we estimate that the use of ICT inputs accounted for nearly one-fourth of the labour productivity growth, representing around 55% of the entire contribution of fixed capital. Third, at a sectoral level, we find that there is a general rise in the weight of ICT in total fixed capital and a general reduction in ICT cost shares driven by the sharp downward trend in the prices of ICT products. However, the contribution of ICT inputs displays a certain sectoral heterogeneity explained by the disparity of accumulation rates of ICT inputs across sectors, although most sectors have experienced a higher contribution to growth in the second half of the 1990s. Finally, at the individual level firms exhibit notable heterogeneity, although a majority recorded higher ICT capital growth rates in the second half of the 90s.

Although ICT capital growth rates have been notable, they are still well below those observed in the US economy. Consequently, they are not sufficiently high to narrow the gap in new technology capital observed between the Spanish and US economies. A final remark concerns TFP growth. The results presented here show a slightly lower TFP growth rate for the second half of the 90s. However, our approach does not allow us to draw any conclusion on the link between ICT growth and TFP growth rates. In other words, the growth accounting framework provides a valuable analysis of the proximate sources of economic growth, but it does not adequately explain which are the underlying factors driving the processes of substitution between factors or which are the causes that lie behind TFP growth. These are the types of issue we plan to address in future research. We think that firm-level data is especially useful to deal with them, since they allow the distinctive features of the technology-intensive firms and of the firms displaying a high productivity growth to be identified.

Table 1

ICT CONTRIBUTION TO VA GROWTH
Results for the whole non-financial market economy (1)

	Total period	1992-1995	1996-2000
1. VA growth rate	**2.85**	**0.97**	**4.35**
Contribution from:			
2. Labour (in hours)	0.57	-1.59	2.30
3. Software	0.16	0.11	0.20
4. Hardware	0.22	0.18	0.25
5. ICT (3+4)	**0.38**	**0.29**	**0.45**
6. Rest of capital	0.80	1.04	0.61
7. Total factor productivity	1.10	1.23	0.99
Cost shares (%) (2)			
8. Software	0.77	0.67	0.86
9. Hardware	1.20	1.53	0.93
10. ICT (8+9)	1.97	2.20	1.79
11. Rest of capital	19.92	22.27	18.04
Growth rate of capital stocks (%) (2)			
12. Software	7.74	5.93	9.18
13. Hardware	7.18	1.37	11.83
14. ICT	7.54	4.40	10.06
15. Rest of capital	0.92	0.26	1.44
Ratio of ICT capital to total fixed capital (%)			
20. Software	2.39	1.91	2.78
21. Hardware	5.18	3.91	6.19
22. ICT	7.57	5.82	8.97
23. Rest of capital	92.43	94.18	91.03
Contribution to VA growth relative to cost shares			
24. Software (3/8)	21.05	17.34	24.01
25. Hardware (4/9)	20.44	11.53	27.56
26. ICT (5/10)	19.84	13.06	25.27
27. Rest of capital (6/11)	4.04	4.63	3.56
Contribution to VA growth relative to total fixed capital share			
28. Software (3/20)	6.95	6.39	7.39
29. Hardware (4/21)	4.26	4.59	4.00
30. ICT (5/22)	5.08	5.11	5.05
31. Rest of capital (6/23)	0.87	1.10	0.68

(1) Computed by averaging sectoral results, weighted by their share in total value-added. Sectoral results correspond to the average for individual firms in the corresponding sector.

(2) Note that the product of average cost share by average capital growth rates is not the same as the average contribution to growth.

Table 2

ICT CONTRIBUTION TO LABOUR PRODUCTIVITY GROWTH Results for the whole non-financial market economy(1)			
	Total period	**1992-1995**	**1996-2000**
Labour productivity growth (2)	2.22	2.90	1.67
contribution from:			
1. Software	0.14	0.12	0.17
2. Hardware	0.20	0.19	0.21
3. ICT (1+2)	**0.35**	**0.31**	**0.38**
4. Rest of capital	0.77	1.36	0.30
5. Total factor productivity	1.10	1.23	0.99
Memorandum items:			
Growth rate of labour	*0.63*	*-1.93*	*2.68*
Capital-labour ratio (3)			
Software	*0.13*	*0.10*	*0.17*
Hardware	*0.17*	*0.09*	*0.24*
ICT	*0.31*	*0.19*	*0.40*
Rest of capital	*21.24*	*22.84*	*19.95*

(1) Computed by averaging sectoral results, weightied by their share in total value-added. Sectoral results correspond to the average for individual firms in the corresponding sector.

(2) In hours

(3) Capital stock (in millions of pesetas) per 1000 hours of labour

Table 3

Sectoral classification and final sample coverage

Sector	Correspondence NACE/93 (2 digit classif.)	Share in total value added (%) (1)	Sample description: Total num obs	Value added sample coverage	Employment sample coverage	Value added per firm (1995 ESP m)	Employees per firm	% of firms with ICT=0
				Annual averages				
1.Agri., Forestry &Fishery	01, 02, 05	6.8	138	0.5	1.6	1157.5	415.9	27.3
2.Fuel and Power Products	10, 14, 23, 40-41	5.4	623	60.8	52.7	25665.2	1040.4	5.3
3.Ferric & Non-Ferric & Metals	27-28	3.1	561	18.5	11.4	4979.3	574.4	6.8
4.Non Metal. Minerals & Mineral Prod	26	1.9	396	16.4	9.5	3950.1	367.4	7.3
5.Chemical Products	24	2.3	896	34.6	28.5	4321.4	383.2	5.8
6.Machinery	29-33	3.3	886	24.0	18.1	4524.7	566.2	2.7
7.Transport Equipment	34-35	2.7	526	50.1	40.0	12636.6	1726.8	6.2
8.Food, Beverages & Tobacco	15-16	4.2	957	21.3	14.1	4563.2	505.5	6.5
9.Textiles,Cloth., Leather & Footw.	17-19	2.0	472	7.0	4.8	1473.1	305.5	12.3
10.Other Manufacturing Products	20,36	1.7	290	6.1	3.2	1751.1	251.4	2.0
11.Paper and Printing Products	21-22	2.1	316	15.2	9.1	5125.7	466.5	5.1
12.Rubber and Plastic Products	25	1.2	198	21.9	17.7	6613.9	789.6	3.3
13.Building and Construction	45	9.9	769	8.0	6.2	4879.0	800.8	10.1
14.Repair, Wholesale,Retail & hostin	50-52	24.7	2078	8.0	8.9	4702.6	788.0	6.8
15.Transport	60-63	7.1	786	24.4	24.0	10929.6	1265.2	4.4
16.Communication Services	64	3.7	62	64.0	52.9	194154.5	13591.5	2.0
17.Other Market Services	70-74	18.1	1561	5.8	6.4	3400.7	553.8	12.7

(1)Taken from Estrada and López-Salido (2001)

TABLE 4

CONTRIBUTION OF ICT PRODUCING SECTORS TO ΔTFP

	1992-1995				1996-2000			
	Δ TFP	Weight in VA	Contribution to ΔTFP total eco. (a)		Δ TFP	Weight in VA	Contribution to ΔTFP total eco. (a)	
	%	%	p.p.	% (b)	%	%	p.p.	% (b)
ICT manufacuring	3.48	0.88	0.03	2.5	1.77	0.87	0.02	1.6
ICT comunications	5.13	2.43	0.12	10.1	5.45	3.07	0.17	16.9
Computer services	1.56	0.68	0.01	0.9	0.54	1.28	0.01	0.7
Total ICT (c)			**0.17**	**13.5**			**0.19**	**19.2**
Memorandum item:								
Total market economy	*1.23*	*100*			*0.99*	*100*		

(a) Computed as the product of ΔTFP and weight in VA
(b) Relative to ΔTFP of total market economy
(c) Computed by adding the contributions of the 3 sectors involved

FIGURE 1

PRICE DEFLATORS FOR INVESTMENT GOODS

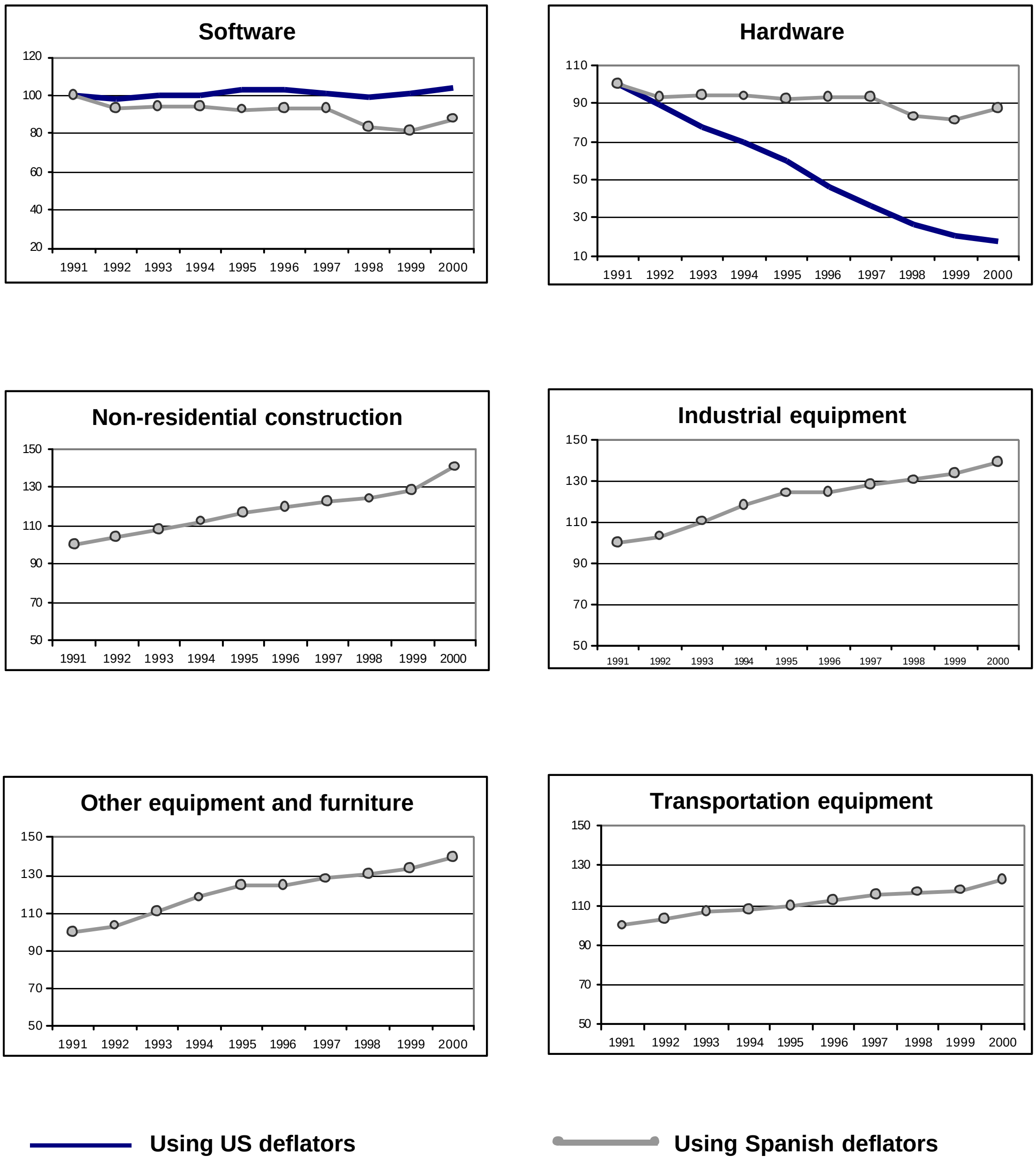
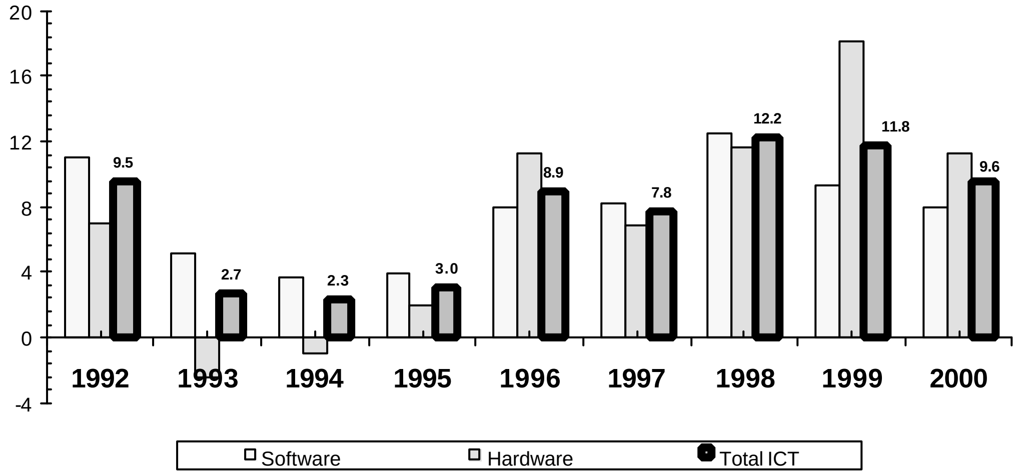


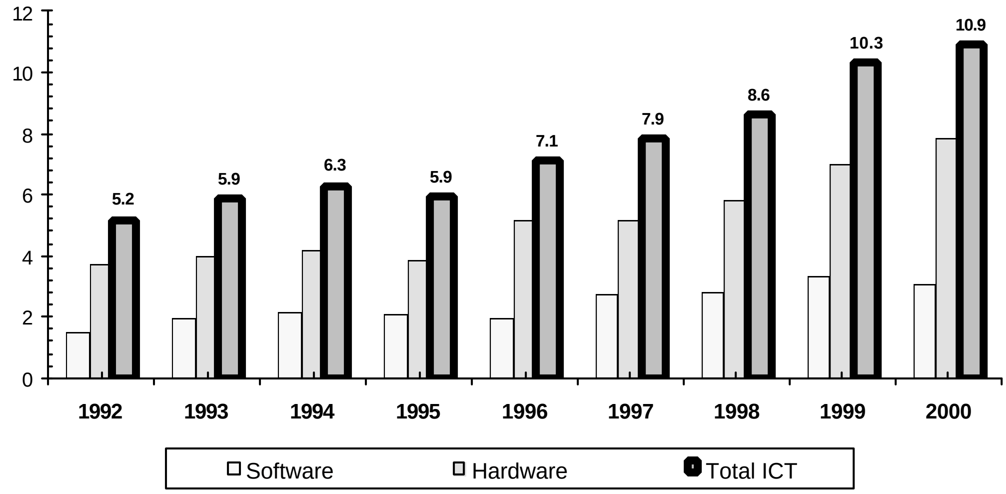
FIGURE 2

1. Growth rates of ICT capital inputs (whole economy)



2. Composition of capital stock (whole economy)

ICT capital / total capital ratio



Figures displayed correspond to the average of sectoral ones, weighted by their shares in total value added.

FIGURE 3

USER COSTS OF CAPITAL (1992=100)

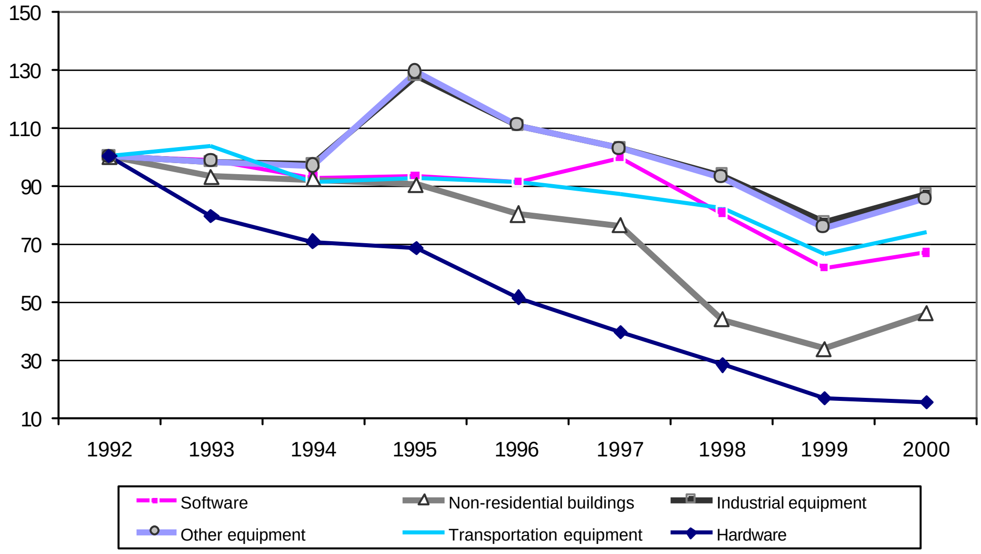


FIGURE 4

Cost shares of ICT capital inputs (whole economy) (%)

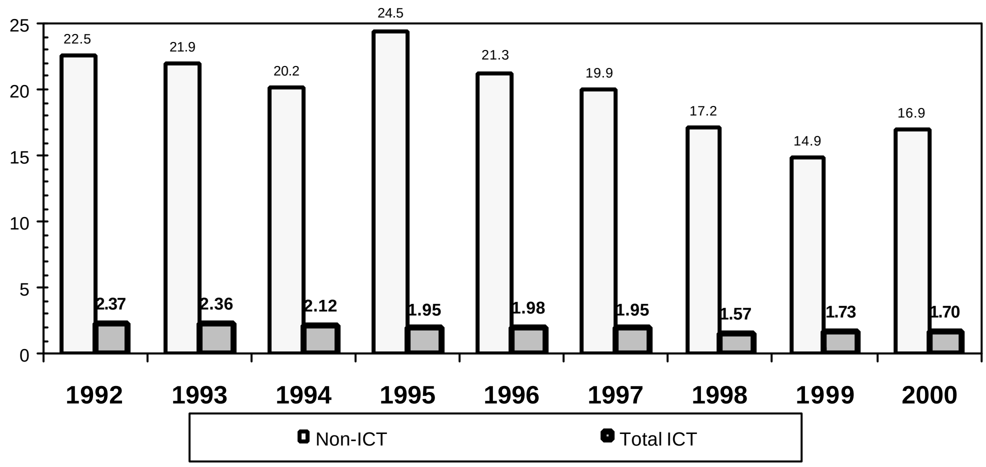
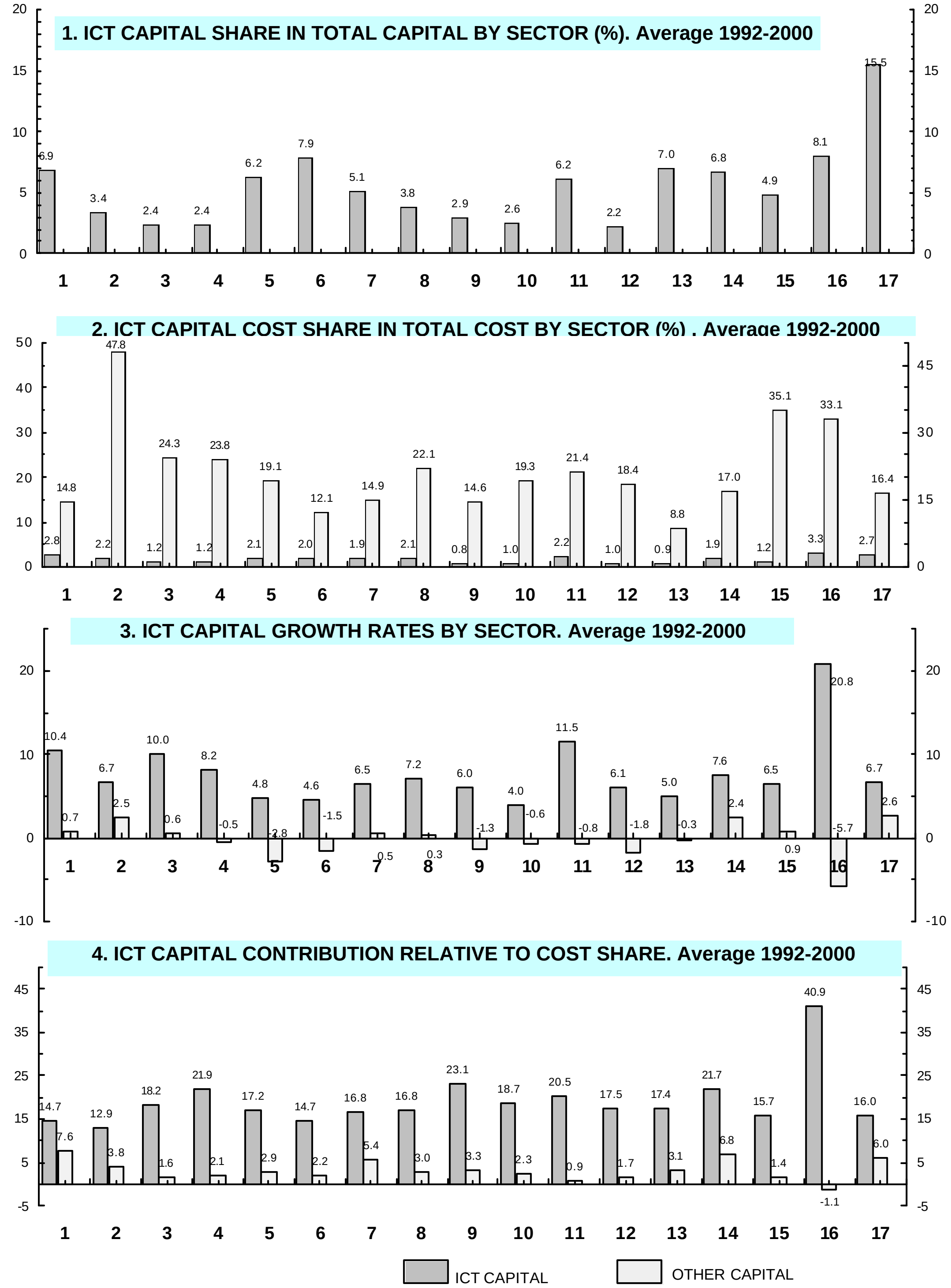


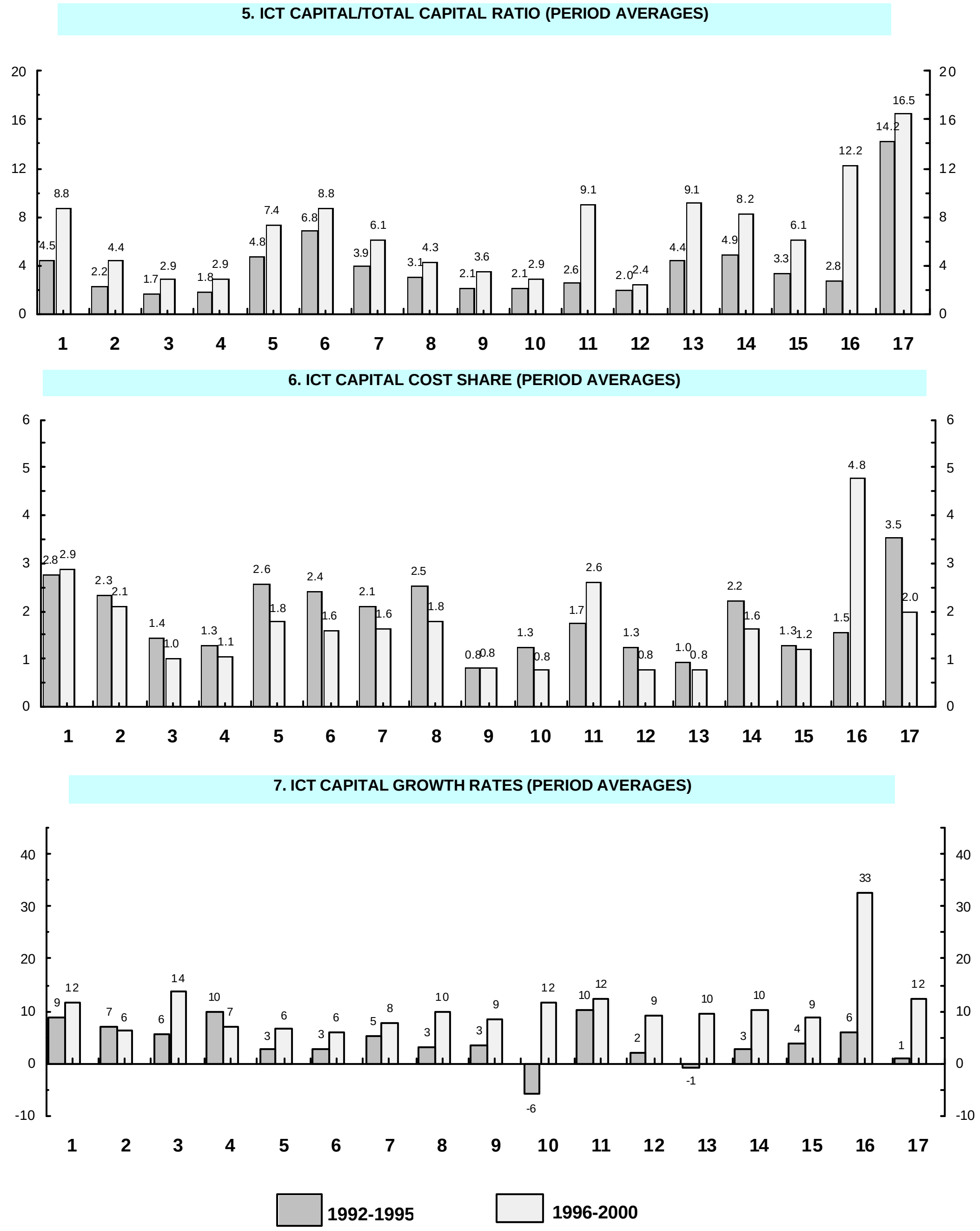
FIGURE 5



Sectors:

1.Agricultural, Forestry and Fishery
2.Fuel and Power Products
3.Ferric & Non-Ferric Ind. & Metals
4.Non Meta.minerals & Mineral Prod.
5.Chemical Products
6.Machinery
7.Transport Equipment
8.Food, Beverages and Tobacco
9.Textiles, Clothing, Leat. & Footw.
10.Other Manufacturing Products
11.Paper and Printing Products
12.Rubber and Plastic Products
13.Building and Construction
14.Repair, Wholesale, Retail & hosting
15.Transport and related services
16.Communication Services
17.Other Market Services

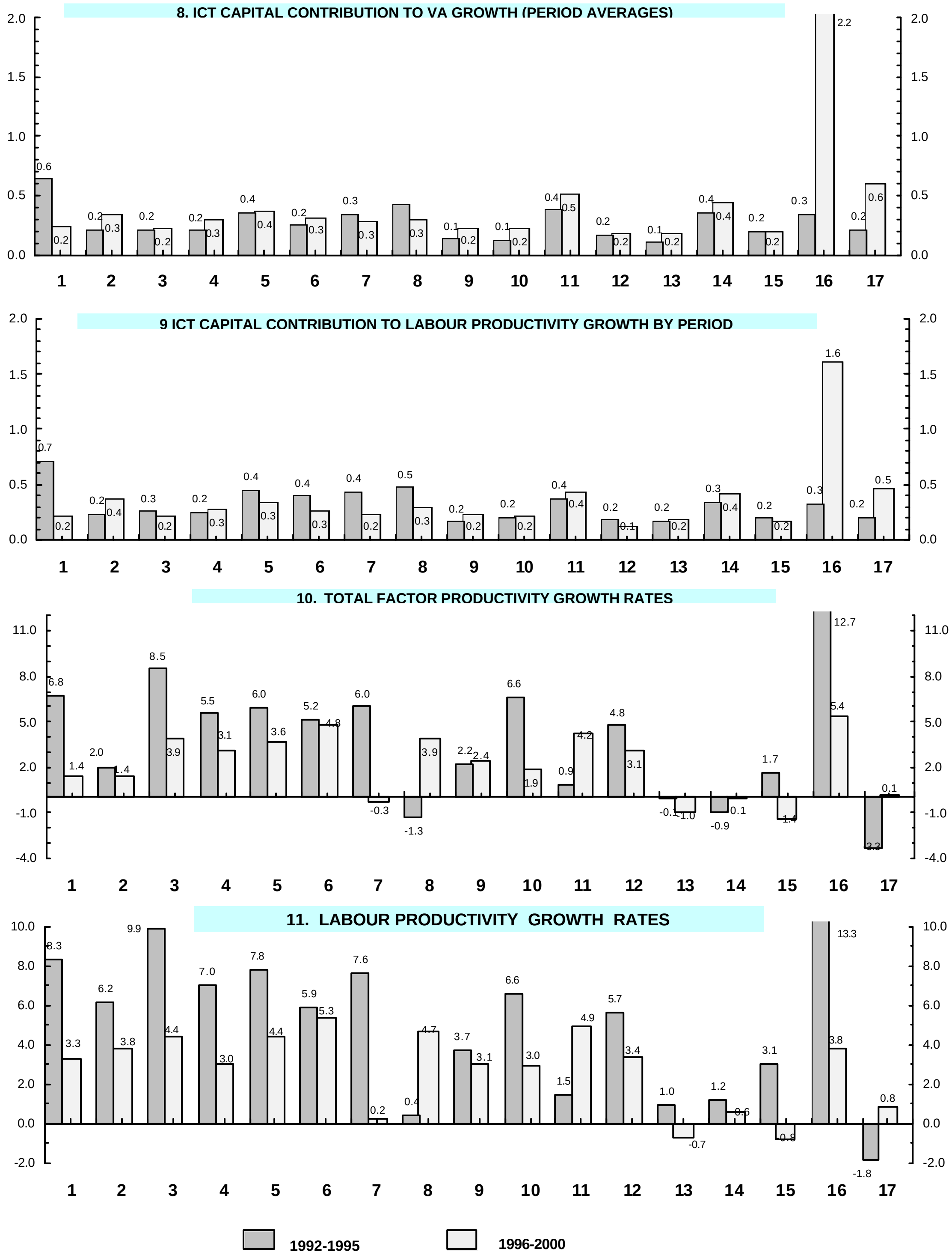
FIGURE 5 (CONT.)



Sectors:

1.Agricultural, Forestry and Fishery
2.Fuel and Power Products
3.Ferric & Non-Ferric Ind. & Metals
4.Non Meta.minerals & Mineral Prod.
5.Chemical Products
6.Machinery
7.Transport Equipment
8.Food, Beverages and Tobacco
9.Textiles, Clothing, Leat. & Footw.
10.Other Manufacturing Products
11.Paper and Printing Products
12.Rubber and Plastic Products
13.Building and Construction
14.Repair, Wholesale, Retail & hosting
15.Transport and related services
16.Communication Services
17.Other Market Services

FIGURE 5 (CONT.)



Sectors:

1.Agricultural, Forestry and Fishery
2.Fuel and Power Products
3.Ferric & Non-Ferric Ind. & Metals
4.Non Meta.minerals & Mineral Prod.
5.Chemical Products
6.Machinery
7.Transport Equipment
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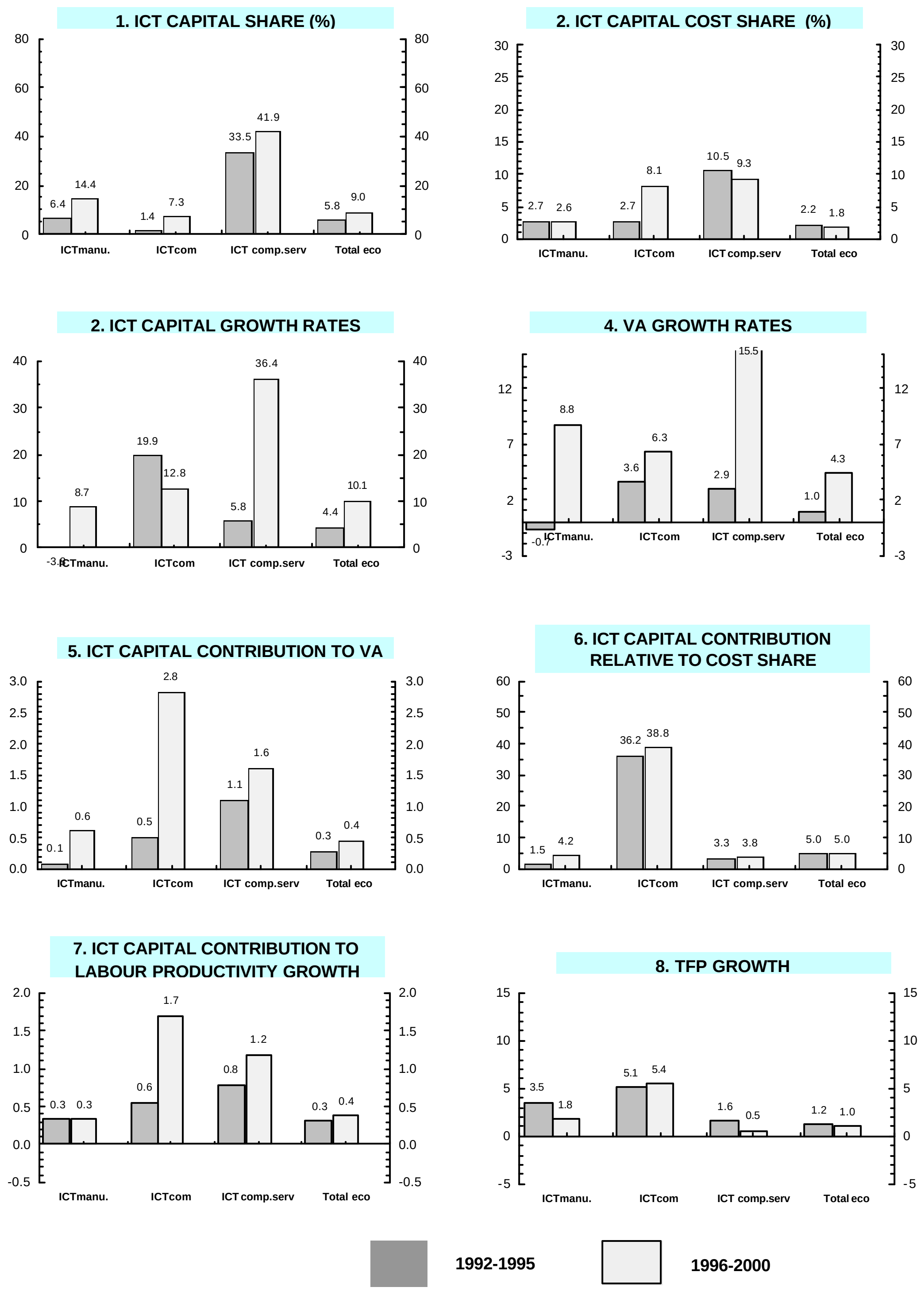
9.Textiles, Clothing, Leat. & Footw.
10.Other Manufacturing Products
11.Paper and Printing Products
12.Rubber and Plastic Products
13.Building and Construction
14.Repair, Wholesale, Retail & hosting
15.Transport and related services
16.Communication Services
17.Other Market Services

FIGURE 6
ICT GROWTH IN ICT-PRODUCING SECTORS



ICT manu: ICT manufacturing (division 30 and 32 and groups 313, 332 & 333 in NACE/93)

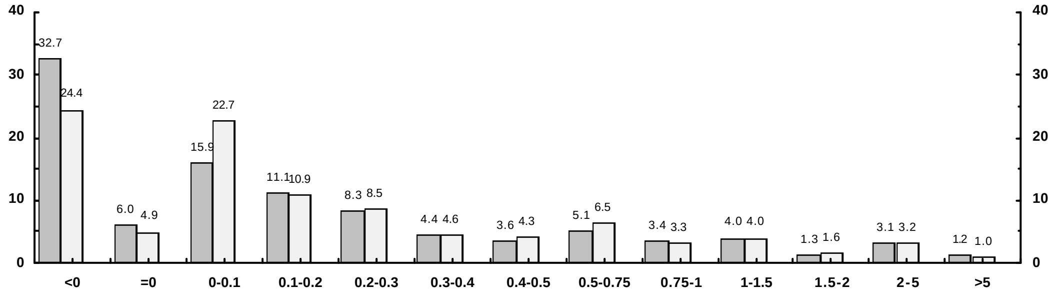
ICT com: ICT Communications (group 642 in NACE/93)

ICTcomp. serv: ICT Computer Services (division 72 in NACE/93)

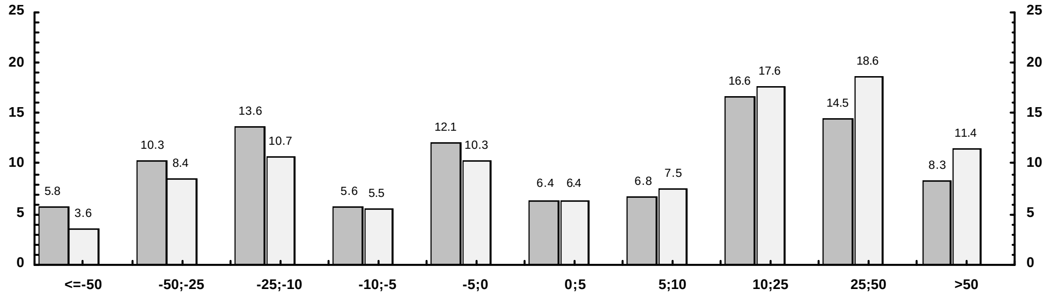
FIGURE 7

CROSS-SECTIONAL DISTRIBUTION OF ICT CAPITAL STOCK VARIABLES (%)

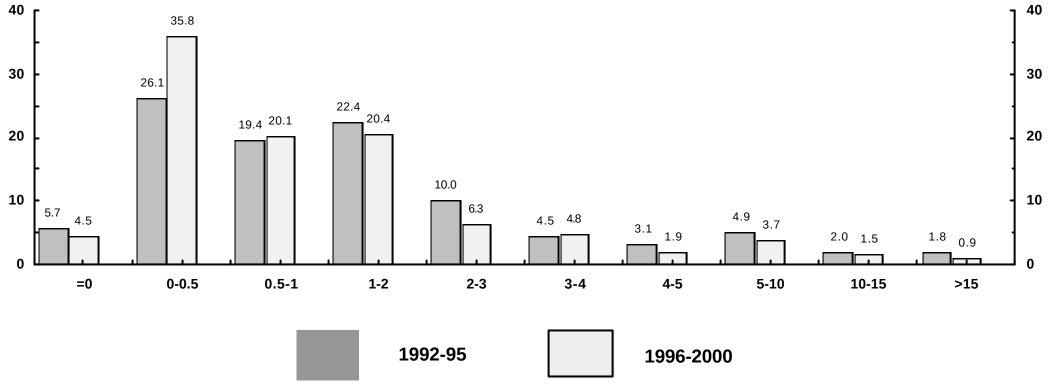
1. CROSS-SECTIONAL DISTRIBUTION OF ICT CONTRIBUTIONS TO OUTPUT GROWTH



2. CROSS-SECTIONAL DISTRIBUTION OF ICT GROWTH RATES



3. CROSS-SECTIONAL DISTRIBUTION OF ICT COST SHARES



Annex 1. The database

The sample

The individual balance sheet data are available over the 1991-2000 period on a yearly basis. The initial sample is an unbalanced panel containing 18,330 observations corresponding to 3,850 firms. This information has been combined with other data sources (both sectoral and economy-wide).

Cleaning of the sample

First, we have excluded those observations for which the available information was insufficient to compute some of the variables considered throughout the analysis, in particular, the average life of the capital stocks. After this step the resulting sample contained 17,931 observations, corresponding to 3,789 firms (830 of them are only available for one period). Second, in order to handle outliers, we have removed those observations within the upper and the lower percentiles of the distributions defined (for each year and sector) in terms of the growth rates of the different capital stocks.

Finally, as we need to compute growth rates to obtain the contribution of the different inputs we lose the first observation for each firm. The final sample is an unbalanced panel containing 11,515 observations corresponding to 2,724 firms. Table A1 reports the composition of the final sample.

Variables and data construction

Value-added (Q): This has been deflated using sectoral value-added deflators from Estrada and López-Salido (2001).

Labour (L): For each firm, we use the average number of hours per year. This value is the result of multiplying the average number of employees per year (available at the firm level) by the average number of hours per employee (taken, at a sectoral level, from Estrada and López-Salido, 2001).

Capital stocks (K_i): In order to convert the book value of capital into market and constant values we have proceeded as follows –following Hall (1990) and Bugamelli and Pagano (2001).[22] First we have computed, for each year and type of capital, its age. We have set the age of capital as the 2-year average of the ratio of total accumulated depreciation to current depreciation. Then, we have calculated the current value of each type of capital as:

$K_{i\,t}$ =[Net book value of type i capital x $P_i(t)$] / $P_i(\text{t-age}_{\,it})$

[22] A very similar procedure is also used by the Central Balance Sheet Office of the Banco de España to construct total capital stocks.

Where $P_i(j)$ is the price deflator for type i capital and year j, t is the current period and age is the above calculated age of capital. Capital stocks at 1995 constant prices were calculated as:

$K_{i\,t}$ = Net book value of type i capital / $P_i(t\text{-age}_{it})$

For these calculations we have taken into account leasing and the revaluations of book value capital made by the firm.

Price indices for capital inputs (P_i): The price indices for non-residential construction (K_{bld}) and transportation equipment (K_{trp}) are taken from the Spanish National Accounts. For industrial equipment (K_{ieq}) and other equipment and furniture (K_{oeq}) a common price index is constructed combining information from the National Accounts, Industrial Domestic Wholesale Prices (IPRI) and Export Wholesale Prices (IVUX). For software (K_{sw}) and hardware (K_{hw}), we compute the price deflators by assuming that the ratio of these deflators to the GDP deflator in Spain is the same as the corresponding ratio in the US. The deflators for these capital inputs in the US economy are taken from US Department of Commerce, Bureau of Economic Analysis ("Chain-Type Price Indexes for Private Fixed Investment in Equipment and Software by Type").

In Section 3, we compare the deflators for hardware and software with an alternative price index obtained from Spanish statistical sources. This price index (common to hardware and software) is constructed combining information from the National Accounts, Industrial Domestic Wholesale Prices (IPRI) and Export Wholesale Prices (IVUX).

Depreciation rates (d_i): With the exception of hardware and software, these have been calculated at a sectoral level. Hardware and software depreciation rates were set equal for all sectors. The software depreciation rate was taken from Whelan (2000), and all others from Fraumeni (1997).

Net rate of return (r): is measured as the average (by year and sector) of the apparent interest rate obtained from the accounting data. The apparent interest rate is defined as the ratio of interest and similar charges to gross debt.

Fiscal correction factor (f): Defined, at the sectoral level, as: $f = \dfrac{(1 - itc_t - t_t z_{st})}{(1 - t_t)}$ where z represents the present value of depreciation expenses, τ represents the corporate tax-rate and itc represents the investment tax credit. z changes by sector and over time and τ and itc over time only.

TABLE A1.1

FINAL SAMPLE DESCRIPTION

1. GENERAL

	Mean	Percentiles 5%	10%	25%	50%	75%	90%
Number of employees	621.14	36.00	75.00	121.07	204.94	427.42	983.00
Value added (1995 millions pta)	5345.95	257.44	401.98	698.00	1388.78	3220.73	8359.02
Sfware capital to total capital ratio	2.72	0.00	0.00	0.00	0.26	1.82	6.23
Hardware capital to total capital ratio	4.94	0.00	0.09	0.43	1.34	3.91	12.44
Total ICT capital to total capital ratio	7.67	0.01	0.17	0.77	2.44	7.14	20.54
Total fixed capital-labour ratio (1)	18.76	0.16	0.41	1.17	2.79	6.30	15.65
Total number of firms	2724						
Total number of observations	11515						

2. By year

Year	Num firms	Num firms with sofw.=0	Num firms with hardw.=0	Num firms with ICT K=0	% of firms with sofw.=0	%of firms with hardw.=0	% of firms with ICT K=0
1992	1386	785	165	137	56.6	11.9	9.9
1993	1320	674	138	109	51.1	10.5	8.3
1994	1310	646	122	103	49.3	9.3	7.9
1995	1332	607	118	98	45.6	8.9	7.4
1996	1410	594	134	109	42.1	9.5	7.7
1997	1403	553	118	93	39.4	8.4	6.6
1998	1307	490	110	83	37.5	8.4	6.4
1999	1125	400	80	63	35.6	7.1	5.6
2000	922	330	65	46	35.8	7.0	5.0

(1) Capital stock (in millions of 1995 pesetas) per 100 employees

Annex 2. The aggregation method

In this paper, the growth accounting exercise is implemented at the firm level. Thus, each component of equations (8) and (12) (that is, the value added growth rate, factor inputs contributions and the TFP growth rate) is computed for each firm in the sample. To obtain the components of equations (8) and (12) for the total non-financial market economy from the components computed at the firm level we take two additional steps. First, we average these components by sector. Second, we obtain the figures for the total non-financial market economy by averaging the sectoral variables involved, weighting the sectors by their share in total value added.

For the sake of robustness, in the first step we consider two alternative sectoral breakdowns (the National Accounts sectoral breakdown into 71 industries and the breakdown into 17 sectors used in Estrada and López-Salido (2001)) and we follow two alternative procedures to go from the individual components to the sectoral ones. In the first one, we compute the sectoral component as the simple average of the individual ones and, in the second one, for each sector we aggregate the individual data for value added and inputs and we then implement the growth accounting exercise at the sectoral level.

The sectoral weights used in the second step are then calculated from data taken from Estrada and López-Salido (2001), in the case of the 17-sector breakdown, and directly from the National Accounts, in the case of the 71-sector breakdown.

Table A2.1 displays growth rates for some basic variables (value added, employment, labour productivity, TFP and capital stock[23]) computed using the four alternative aggregation methods implemented and compares them with these in the Estrada and López-Salido (2001) sectoral database, which is taken as a benchmark. As can be observed from this table, the method that gives growth rates for the basic variables closest to the benchmark is that based on the 17-sector breakdown and where the sectoral figures computed as simple averages of the individual ones. Thus, in the main text, we discuss the results corresponding to this case. Nevertheless, our conclusion regarding the ICT contribution to growth for the aggregate economy is robust to the alternative procedures of aggregation of the ICT contributions (see Table A2.2).

[23] Since the growth rates of these variables are compared with the corresponding growth rates in Estrada and López-Salido (2001), the capital stock for this table has been constructed using the deflators directly obtained from Spanish statistical sources. This accounts for the slight differences in the figures for TFP growth rates between this table and Table 1.

TABLE A2.1

COMPARING RESULTS OF DIFFERENT AGGREGATION METHODS (*)										
		Growth rates					Differences with benchmark			
Variable	Period	Benchmark ELS (1)	Adding firms NA sectors (2)	Adding firms 17 sectors (3)	Averaging firms NA sectors (4)	Averaging firms 17 sectors (5)	Adding firms NA sectors (2)	Adding firms 17 sectors (3)	Averaging firms NA sectors (4)	Averaging firms 17 sectors (5)
Value added	1991-95	1.14	1.25	0.70	1.11	0.97	0.12	-0.43	-0.03	-0.17
	1996-00	3.70	5.50	5.93	5.03	4.35	1.80	2.23	1.34	0.65
Employ-ment (hours)	1991-95	-1.43	-1.40	-1.60	-1.81	-1.93	0.02	-0.18	-0.38	-0.50
	1996-00	2.78	3.40	2.26	2.75	2.68	0.62	-0.52	-0.03	-0.10
Labour productivity	1991-95	2.56	2.66	2.31	2.92	2.90	0.10	-0.26	0.36	0.34
	1996-00	0.92	2.09	3.67	2.29	1.67	1.18	2.75	1.37	0.75
Total factor productivity	1991-95	1.23	1.78	0.77	1.20	1.29	0.55	-0.46	-0.03	0.06
	1996-00	0.63	1.86	3.09	1.72	1.08	1.23	2.46	1.09	0.45
Capital stock	1991-95	2.22	1.99	3.35	0.53	0.49	-0.23	1.13	-1.69	-1.73
	1996-00	3.53	2.08	1.08	2.72	2.72	-1.44	-2.45	-0.81	-0.80

Smallest difference with benchmark
Second smallest difference with benchmark

(1) Taken from Estrada and López-Salido (2001)
(2) For each of the 71 NA industries, variables involved are obtained by aggregating individual values
(3) For each of the 17 sectors considered, variables involved are obtained by aggregating individual values
(4) For each of the 71 NA industries, variables involved are obtained by averaging individual values
(5) For each of the 17 sectors considered, variables involved are obtained by averaging individual values
(*) For all of the aggregation methods, total market non-financial economy values are obtained by averaging sectoral figures weighted by their share in total value added

TABLE A2.2

ICT CONTRIBUTION TO VA GROWTH Results for the whole market economy with different aggregation methods (*)								
	Adding firms				Averaging firms			
	17 sectors (1)		NA sectors (2)		17 sectors (3)		NA sectors (4)	
Period	1992-95	1996-2000	1992-95	1996-2000	1992-95	1996-2000	1992-95	1996-2000
Value added growth rate	**1.25**	**5.50**	**0.70**	**5.93**	**0.97**	**4.35**	**1.11**	**5.03**
Contribution from:								
Labour	-0.73	2.98	-1.19	2.18	-1.59	2.30	-1.44	2.32
Software capital	0.04	0.15	0.07	0.14	0.11	0.20	0.11	0.18
Hrdware capital	0.05	0.21	0.12	0.20	0.18	0.25	0.18	0.25
ICT capital	**0.09**	**0.36**	**0.19**	**0.34**	**0.29**	**0.45**	**0.29**	**0.42**
Non ICT capital	0.21	0.38	1.03	0.39	1.04	0.61	1.15	0.65
Total factor productivity	1.68	1.79	0.67	3.02	1.23	0.99	1.11	1.64

(1) For each of the 71 NA industries, variables are obtained by aggregating individual values
(2) For each of the 17 sectors considered, variables are obtained by aggregating individual values
(3) For each of the 71 NA industries, variables are obtained by averaging individual values
(4) For each of the 17 sectors considered, variables are obtained by averaging individual values
(*) For all of the aggregation methods, total market non-financial economy values are obtained by averaging sectoral figures weighted by its share in total value added

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