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

IGNACIO HERNANDO
SOLEDAD NÚÑEZ
Banco de España

This paper applies a well-established growth accounting framework to measure the contribution of ICT inputs to output and labour productivity growth in Spain, using a sample of 1300 firms per year over 1991-2000. Firm-level data are helpful to overcome the availability lags and the mismeasurement of capital stocks associated with the use of aggregate data. We find that: 1) The use of ICT inputs has made a positive and significant contribution to output and productivity growth. 2) This contribution was higher in the second half of the 1990s. 3) At a sectoral level, there is a general rise in the share of ICT in total capital and a general reduction in ICT cost shares.

Keywords: Information and communication technologies, growth accounting, technological change.

(*JEL* O33, D24, L63)

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

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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 total factor productivity (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 also entail some problems[1], 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 output and labour 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 labour productivity growth from the use of labour and different types of capital (ICT among them). In so doing, we compute the growth rate of total capital services as a weighted average of the growth rates of the different types of capital, with weights being based on their respective user costs. 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 –Jorgenson and Stiroh (2000), Oliner and Sichel

[1] First, capital stock figures have to be converted from book value to market value. Second, typically there is implicit bias in the composition of the panels. In particular, our sample is biased towards large and manufacturing firms.

(2000), Schreyer (2000), Colecchia and Schreyer (2002) and Daveri (2001)-. 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 Banco de España Central Balance Sheet Data. The final sample includes about 1300 firms per year and it provides information for sufficiently detailed breakdowns of capital.

The use of micro data enables the contribution of ICT inputs to output growth to be characterized both at the firm and at the sectoral level. Nevertheless, 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 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. Given the uneven sectoral coverage in our sample and the assumptions needed to construct an appropriate (hedonic) price deflator for ICT capital, our findings should be viewed with some caution.

Our results suggest that the ICT contribution to growth and ICT capital accumulation rates have been significant although quantitatively smaller than in the US or in other European countries. Thus, according to Oliner and Sichel (2000), over the period 1996-1999, ICT capital explained almost one-quarter of each percentage point of US output growth, while this figure was around 0.10 pp for the Spanish case in the second half of the nineties (1996-2000). In the case of some European countries, Colecchia and Schreyer (2002) find that ICT capital accounted for 13% of output growth in France, 14% in the UK, 19% in Italy and 20% in Germany. Over the period 1996-1999, Oliner and Sichel (2000) 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%. These growth rates can be considered as low if we take into account that there is a 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 substantial differences between Daveri's study and ours. First, Daveri uses aggregate data from a very different data set (ICT expenditure taken from WITSA/IDC and National Accounts OECD series). More specifically, given the lack of information on ICT investment, Daveri computes it by assuming that the ratio of ICT investment to ICT expenses is equal to that observed for the US. Second, he 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. Third, Daveri's study refers only to the whole economy.

The rest of the paper is organised as follows. Section 2 presents the analytical framework. Section 3 describes the construction of the capital stocks and the user costs of the capital inputs. A more detailed description of the sample and the definitions of variables is relegated to Appendix A1 while Appendix A2 discusses the choice of the price indices for capital inputs. 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 neoclassical 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) and Daveri (2001), among others. Our main departures from these authors are twofold. First, we use individual firm data, and, second, following R. Hall (1990), we adopt a cost-based approach and do not impose perfect competition[3].

We start from a Cobb-Douglas production function (F) that relates firm value added (Q) to seven inputs[4]: labour (L), software (K_{sw}),

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

[3] Given that we use individual data on a yearly basis, we consider this strategy more appropriate than a revenue-based approach. Note that most firms present non-zero profits and, consequently, labour plus capital income shares do not add up to one.

[4] Because of data limitations on intermediate inputs, we use value added instead of gross production. A main advantage of this approach is that aggregate value-

hardware (K_{hw}), non-residential buildings (K_{bld}), industrial equipment (K_{ieq}), other equipment and furniture (K_{oeq}) and transportation equipment (K_{trp}). Thus:

$$Q = \theta F\left(L, K_{sw}, K_{hw}, K_{bld}, K_{ieq}, K_{oeq}, K_{trp}\right) \qquad [1]$$

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

By considering six types of capital inputs, we have gone as far as the data allowed us in order to be able to isolate the contribution of ICT capital from the contribution of other capital inputs, on the one hand, and to avoid the aggregation bias associated with internal shifts in the composition of inputs, on the other. Therefore, we follow the approach first suggested by Jorgenson and Griliches (1967) of computing aggregate capital services as the weighted sum of the services of different capital types, with weights based on the respective user costs (instead of market prices). The rationale for this approach is that, in general, each type of asset is associated with a specific flow of capital services which, in turn, is assumed to be strictly proportional to its respective capital stock. Since the ratio between the flow of capital services and the capital stock differs across assets, the aggregate capital stock is not the same as aggregate capital services. Thus, user cost weights provide a way to incorporate differences in the productive contribution of different assets as the composition of capital changes[5]. In this respect, it is worth highlighting that the explicit consideration of the shifting composition of the capital stock is likely to result in, as is later discussed, a higher growth rate of the capital input and a corresponding reduction in the growth of TFP.

Computing growth rates as:

$$\triangle q = \triangle\theta + \frac{L}{Q}\frac{\partial F}{\partial L}\triangle l + \sum_i \frac{K_i}{Q}\frac{\partial F}{\partial K_i}\triangle k_i \qquad i = sw, hw, bld, ieq, oeq, trp \qquad [2]$$

added growth is a weighted average of value-added growth across industries (with weights being sectoral value-added shares). Similarly, aggregate value-added based TFP and aggregate inputs contributions are obtained averaging the corresponding sectoral figures. In contrast, a drawback of this approach is that value-added TFP is not an exact indicator of technical change since it includes technical change embodied in intermediate inputs.

[5] See also McGuckin and Stiroh (2002) for a thorough discussion on the importance of using a detailed breakdown of capital in order to avoid the substantial 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 the same.

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

Using first order conditions for cost minimization and given that, with constant returns, marginal cost (mc) is equal to average cost at the cost minimization value of inputs, we can write:

$$\frac{\partial F}{\partial L} = \frac{w}{mc} = \frac{w\ L}{w\ L + \sum r_i k_i} \frac{Q}{L} = \alpha_L \frac{Q}{L} \qquad [3]$$

$$\frac{\partial F}{\partial K_i} = \frac{r_i}{mc} = \frac{r_i K_i}{w\ L + \sum r_i k_i} \frac{Q}{K_i} = \alpha_{K_i} \frac{Q}{K_i} \qquad [4]$$

where r_i is the rental price of capital i, w is the labour market wage and α_i is the cost share of input i. Substituting [3] and [4] in [2]:

$$\triangle q = \sum_i \alpha_{k_i} \triangle k_i + \alpha_L \triangle l + \triangle TFP \qquad [5]$$

Thus, in equation [5], each input's contribution is obtained by multiplying its rate of change by each factor's share in total cost (a_i)[6]. 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 [5] yields:

$$\triangle q = c_l + c_{ITC} + c_{OTHER\ K} + \triangle TFP \qquad [6]$$

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. In its turn, the contribution of ICT capital

[6] An alternative approach would be to estimate the parameters of the production function. Although such an approach does not require the introduction of the neoclassical assumptions, it requires assuming the homogeneity of the parameters of the production function, at least, across sectors. See Brynjolfsson and Hitt (1996, 2002) for recent papers adopting a microeconometric approach.

results from the addition of the contributions of hardware and software while the contribution of non-ICT capital is the sum of the contributions of the remaining capital inputs.

Alternatively, by rearranging equation [5] we can obtain a similar decomposition for labour productivity growth:

$$\triangle q - \triangle l = cl_{ITC} + cl_{OTHER\ K} + \triangle TFP \qquad [7]$$

where cl_{ICT} is the contribution of ICT capital to labour productivity growth and $cl_{OTHER\ K}$ is the contribution of non-ICT capital. Now, each input's contribution is obtained by multiplying each factor's share in total cost (α_i) by the rate of change of the ratio between each factor and labour ($\triangle k_i - \triangle l$). Therefore, 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. Hence, this framework represents a limited approach to understanding the process of economic growth. It does not adequately explain what are the underlying factors driving the substitution processes between factors or what are the causes behind the growth of TFP.

In our case, we calculate each component of equations [6] and [7] (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 [6] and [7] 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. More precisely, in this step, we consider the sectoral breakdown (17 sectors) used in Estrada and López-Salido (2001) and we compute the sectoral contributions as simple averages of the individual ones[7]. In the second

[7] 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 the 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. In Hernando and Núñez (2002), we discuss the choice of the aggregation method and we present the results for alternative procedures of aggregation of the information computed at the individual level.

step, 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 from Estrada and López-Salido (2001).

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. This section describes the method of construction of these two elements while in Appendix A2 we discuss in detail our choice of price indices for capital inputs as these are an essential component in the computation of both variables. We argue in favour of using hedonic prices for ICT capital inputs in order to take into account quality changes and we discuss how the results of the growth accounting decomposition are affected by using an alternative, non-hedonic set of price deflators.

3.1 Capital stocks

Our database provides accounting data corresponding to the six types of capital assets already enumerated: 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 data, software capital comprises successful R&D investment, and hardware capital includes communications equipment. 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 described in Appendix A2, 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[8].

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

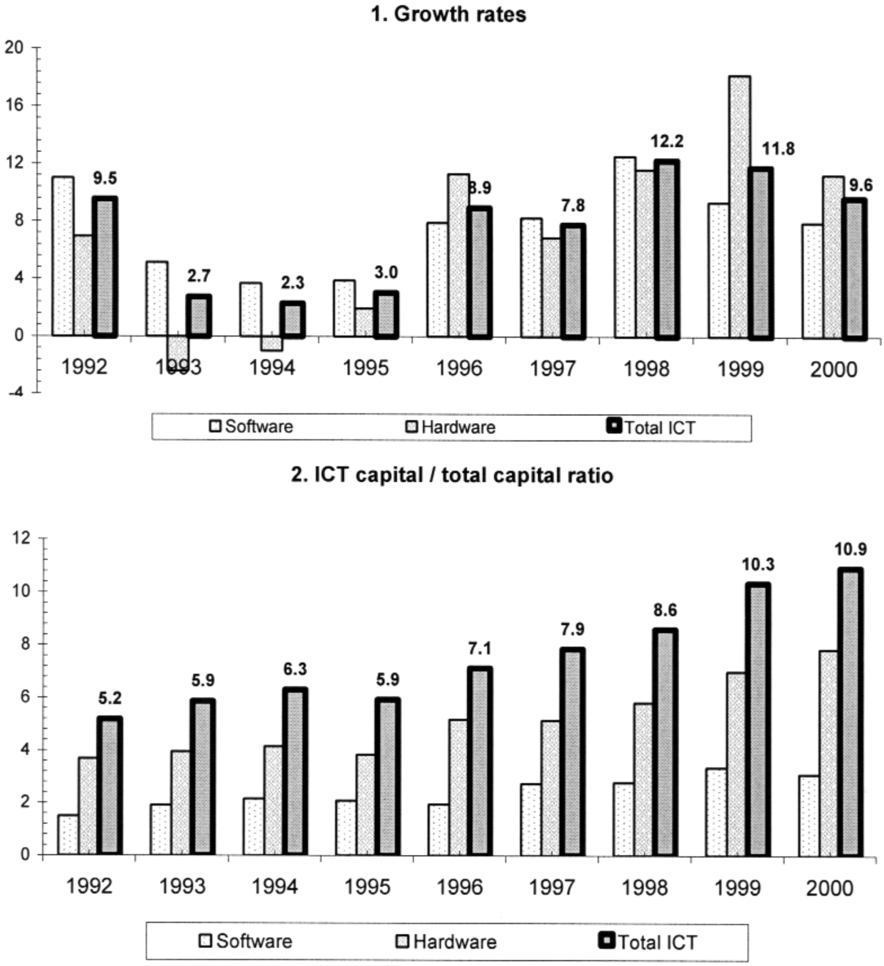
[8] Further details on the computation of the capital stocks are given in Appendix A1.

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 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) might be biased downwards.

Figure 1 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.

To take into account these relevant changes in the composition of capital, the different capital inputs must be weighted by their user costs to implement the growth accounting decomposition. As previously mentioned, the particular method of adjustment for the shifting composition of capital (i.e, the weighting scheme used) has an effect on the relative magnitudes of the growth rate of the capital input and of the

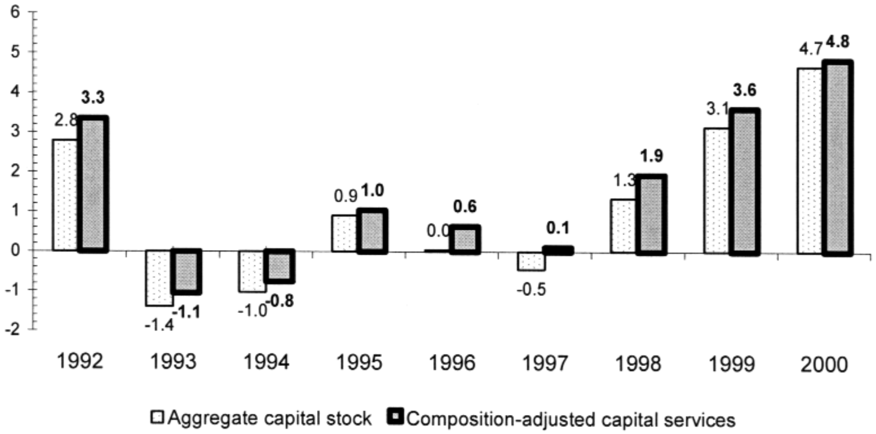
FIGURE 1
ICT capital inputs (whole economy)



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

growth rate of TFP. To illustrate this aspect, Figure 2 compares the growth rates of the aggregate capital stock (where the different types of capital are weighted by their market prices) and the growth rates of the composition-adjusted capital services (where the different types of capital are weighted by their user costs). The composition-adjusted series displays higher growth rates over the whole period, implying that the adjustment for the changing composition of capital increases the growth rate of the capital input and causes a corresponding reduction in the TFP growth rate.

FIGURE 2
Growth rates of aggregate capital input (whole economy)



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

3.2 Cost shares

Each factor's cost share is defined as the ratio of the cost of the input to the 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 choice of the acquisition price is discussed in Appendix A2 and the fiscal correction factor, which is constructed at a sectoral level, is described in more detail in Appendix A1. This fiscal correction factor, which is assumed to be common to all types of capital, reflects taxes and fiscal incentives.

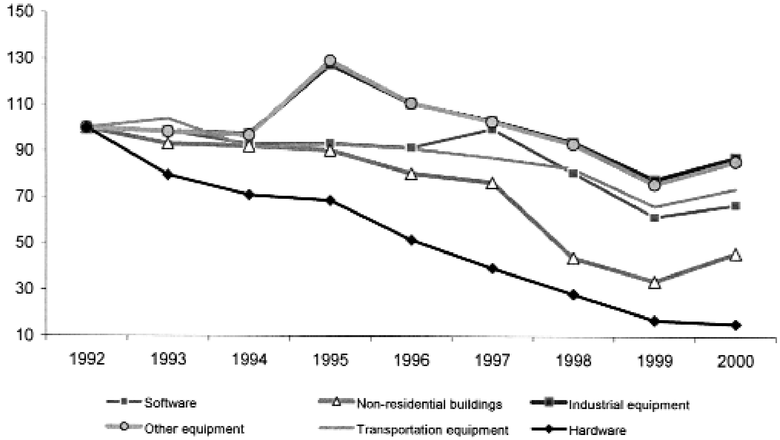
The gross rate of return for capital input K_i is given by the following expression:

$$R_i = r + \delta_i - \pi_i$$

where r is the net rate of return common to all types of capital (representing the opportunity cost of the investment), δ_i is the depreciation rate (which proxies for the loss in market value due to ageing) and π_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[9], 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 are 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.

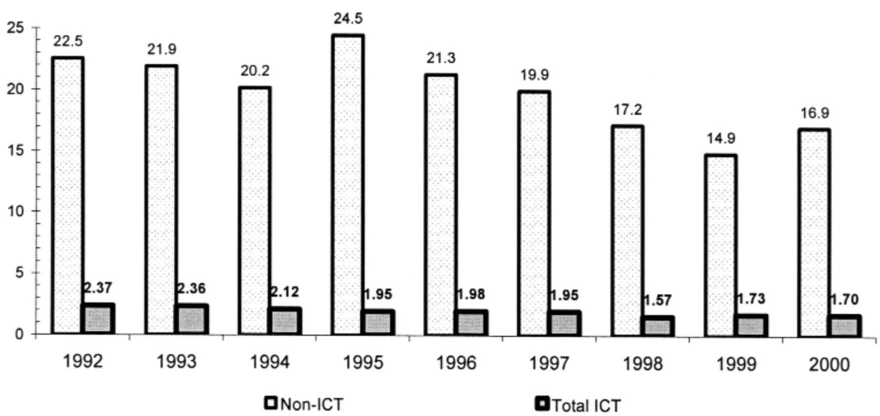
FIGURE 3
User costs of capital (1992=100)



[9]That is $(r + \delta_i - \pi_i)\,\frac{P_{it}K_{it}}{P_{i95}K_{it}}$, where $P_{it}K_{it}$ is capital input i, in nominal terms, and $P_{i95}K_{it}$ is capital input i at constant prices.

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.

FIGURE 4
Cost shares of ICT capital inputs (whole economy) (%)



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 [6] and [7] 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 [6] and [7] at the individual level. Next, by taking sectoral averages for each of these components, we obtain a decomposition of output growth at the sectoral level[10]. 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 and labour productivity growth. The first column reports the results for the overall period, 1992-2000, while columns 2 and 3 present the results for the periods 1992-1995 and 1996-2000. 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, of which 0.14 was explained by computer software and 0.20 by hardware[11]. Similarly, over this period, value added for the non-financial market economy rose at an annual average rate of 2.85% and the contribution of ICT capital to its growth rate represented 0.38 percentage points. The corresponding contributions of computer software and hardware were of 0.16 and 0.22 percentage points, respectively. Therefore, the ICT contribution to both output and labour productivity growth were small during the 1990s, being around half of the contributions 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%. Nevertheless, the contribution of ICT capital to output and labour productivity growth was moderate because ICT capital still represents a very modest fraction of total capital stock (7.6%) and so

[10] 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 Hernando and Núñez (2002) for detailed results).

[11] In order to illustrate the importance of using hedonic prices to take into account quality changes, we have conducted the same exercise using national (non-hedonic) price indices for the ICT inputs. The results based on these alternative price indices are reported in Appendix A2.

TABLE 1
ICT contribution to value added and labour productivity growth
Results for the whole non-financial market economy (1)

	Total period	*1992-1995*	*1996-2000*
1. Labour productivity growth (2)	*2.22*	*2.90*	*1,67*
contribution from:			
2. Software	0.14	0.12	0.17
3. Hardware	0.20	0.19	0.21
4. ICT (1+2)	*0.35*	*0.31*	*0.38*
5. Rest of capital	0.77	1.36	0.30
6. Total factor productivity	1.10	1.23	0.99
7. Value-added growth rate	*2.85*	*0.97*	*4.35*
contribution from:			
8. Labour (in hours)	0.57	-1.59	2.30
9. Software	0.16	0.11	0.20
10. Hardware	0.22	0.18	0.25
11. ICT (3+4)	*0.38*	*0.29*	*0.45*
12. Rest of capital	0.80	1.04	0.61
13. Total factor productivity	1.10	1.23	0.99
Cost shares (%) (3)			
14. Software	0.77	0.67	0.86
15. Hardware	1.20	1.53	0.93
16. ICT (8+9)	1.97	2.20	1.79
17. Rest of capital	19.92	22.27	18.04
Growth rate of inputs (%) (3)			
18. Labour	0.63	-1.93	2.68
19. Software	7.74	5.93	9.18
20. Hardware	7.18	1.37	11.83
21. ICT	7.54	4.40	10.06
22. Rest of capital	0.92	0.26	1.44

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

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.

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 average annual contribution to labour productivity growth reached 0.38 percentage points, up from 0.31 in the period 1992-1995. The increase in the ICT contribution to annual value-added growth was more intense, reaching 0.45 percentage points in the period 1996-2000, 55% higher than the average contribution for the period 1992-1995. Conversely, non-ICT capital contributions have significantly decreased. The increase in the ICT contribution to labour productivity growth is sharper, when measured in relative terms. 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. These results suggest then that the slowdown in labour productivity growth during the second half of the 1990s 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. According to these results, only 20% of the labour productivity slowdown is explained by total factor productivity slowdown[12]. This fact is the outcome of a growth pattern, over the second half of the nineties, characterized by a very intensive employment creation.

Third, the rise in the ICT contributions to output and labour productivity growth during the second half of the 1990s 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, 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 output and labour productivity 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 that, the sharp decline

[12] Moreover, this percentage is even lower in other data sources using non-hedonic price deflators and assuming only one type of capital. For instance, according to the figures published in Banco de España (2002), the total factor productivity slowdown accounts for less tan 10% of the labour productivity slowdown. Labour productivity growth dropped from 2% in 1990-95 to 0.9% in 1996-2000, the corresponding figures for TFP are 0.6% and 0.5%.

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

Comparing these results with those found by Vijselaar and Albers (2002) for the euro area, it appears that, in relative terms, the ICT contribution to labour productivity growth during the 1990s has been of a similar magnitude in Spain and in the euro area[13]. Thus, while these authors estimate an ICT contribution of 0.16 pp for each percentage point of labour productivity growth over the period 1991-1999, we find the same figure for the Spanish case during the period 1992-2000. Moreover, as in the Spanish case, Vijselaar and Albers find that this contribution accelerated over the 1990s, from 10% in the first half to 28% in the second half of the decade, in terms of relative contributions. Finally, these authors also find that the labour productivity growth decrease in the euro area during the second half of the decade can be attributed to both a decline in TFP growth, and to a decrease in the rate of capital deepening of non-ICT capital[14].

4.2 Sectoral results

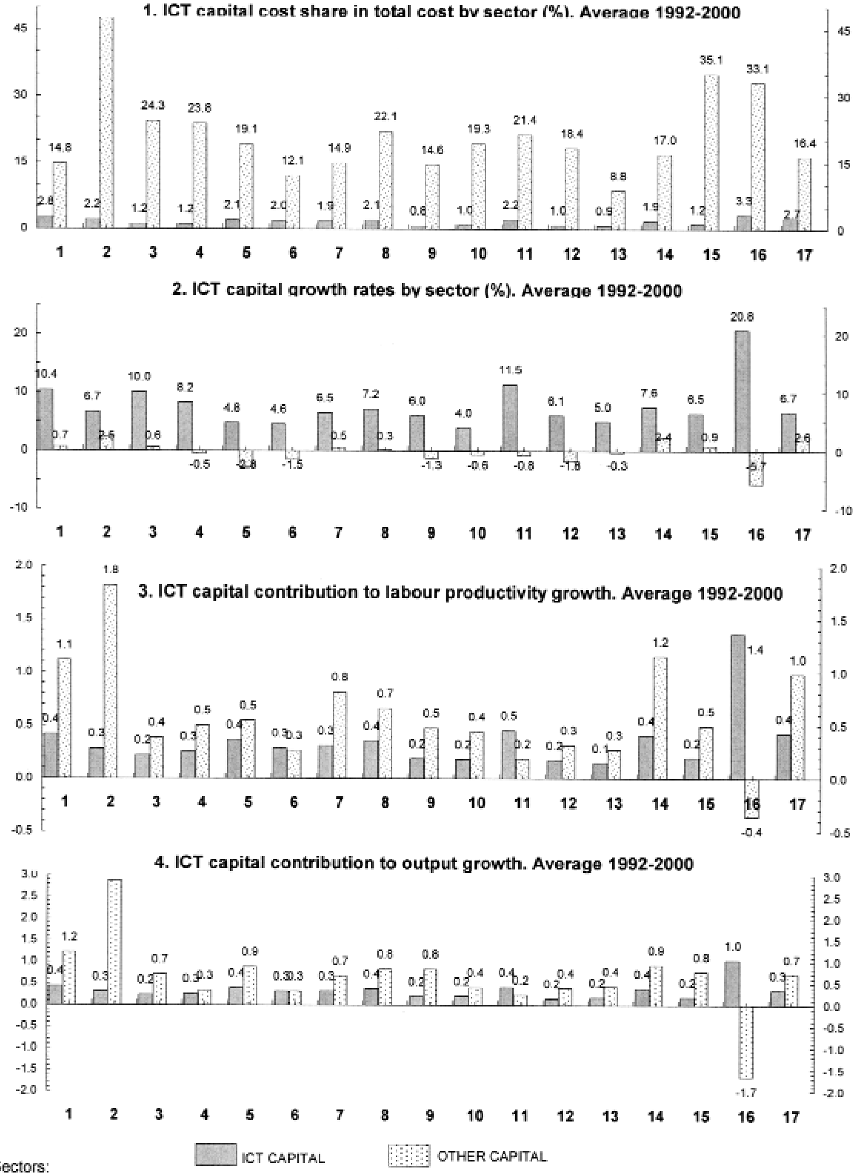
Figure 5 offers a summary of the results at a sectoral level of the growth accounting decomposition. Panel 3 of Table A1 provides detailed information on the sectoral breakdown we have considered. For most industries, sample coverage can be considered as relatively high, although for six of them it is lower than 15% (in terms of value added), and, therefore, the results for these sectors should be viewed with more caution.

Panels 1 to 4 of Figure 5 present sectoral ICT cost shares, ICT capital growth rates and the contributions of ICT capital to value added and labour productivity growth, comparing them with the corresponding

[13] These comparisons should be viewed with caution, due to different sources of data, methodological differences related to price deflators and differences in the output concept (total economy versus market economy).

[14] Other studies that report results on the ICT capital contribution to growth for other economies are Colecchia and Schreyer (2002), for 9 OECD countries, and Daveri (2001), for 18 OECD countries and Oulton (2001) for the UK. Notwithstanding the caveats applying to these comparisons, according to the results reported in these studies, the relative ICT capital contribution to output growth has been higher in some other European countries and, especially, in the US, than in Spain. Interestingly, all these studies find an acceleration of the ICT capital contribution to growth over the 1990s for most countries considered.

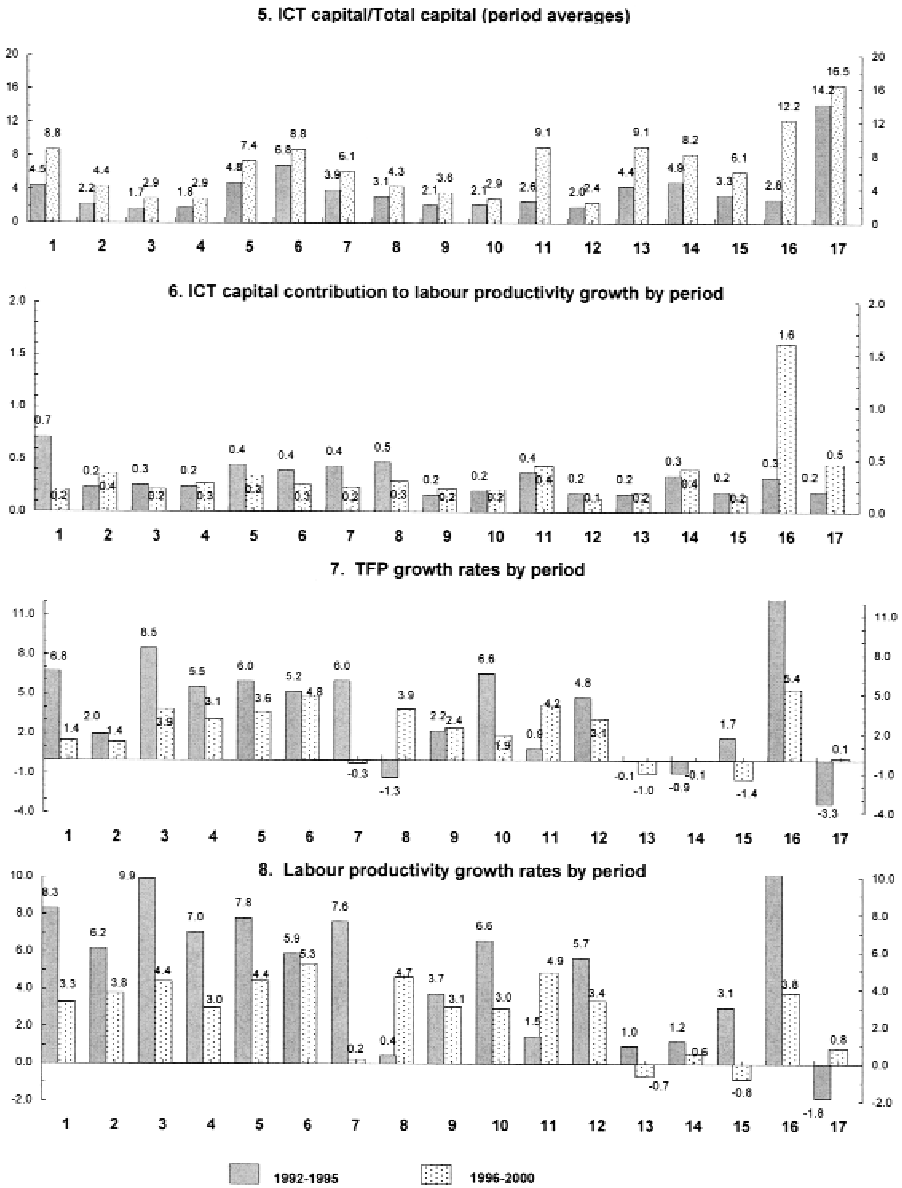
FIGURE 5
ICT capital inputs (sectorial decomposition)



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
ICT capital inputs (sectorial decomposition) *(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

figures for non-ICT capital. 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 display a very small ICT cost share (see panel 1 of Figure 5), ranging from 0.8% (for Food, Beverages and Tobacco) to 3.3% (Communication Services), reflecting the small ICT capital share in total fixed capital. However, throughout the period considered, all sectors experienced a significant ICT capital growth rate, contrasting with that for non-ICT capital (see panel 2). Given the modest fraction of new technology capital, the average ICT contribution to labour productivity growth was small, ranging from 0.15 percentage points for Rubber and Plastic Products to 1.4 pp for Communication Services (see panel 3). Similar figures are found for the sectoral ICT contributions to output growth. However, for all sectors these contributions were, relative to cost shares, much higher than that of the non-ICT capital stock.

Second, all sectors have experienced a rise in the share of ICT capital in total fixed capital throughout the period considered (see panel 5). In most sectors, this substitution of ICT capital for non-ICT capital, explained by relative price developments, has 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, this acceleration being especially remarkable for Communication Services. In spite of these accumulation rates, cost shares have been lower in the second half of the analysed period for most sectors, reflecting the significant decline experienced in ICT capital good prices.

Third, for most sectors (13), the ICT growth rate acceleration outweighed the decline in the cost share, and, consequently, the ICT contribution to output growth increased in 1996-2000 relative to 1992-1995. However, in terms of labour productivity growth, only 9 sectors experienced a higher ICT contribution, in absolute terms, in the second half of the 1990s (see panel 6), despite the general rise in ICT capital deepening. Nevertheless, it is interesting to note that labour productivity growth was lower in most sectors during 1996-2000 (see panel 8).

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.

Finally, 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[15]. What is more uncertain is whether the use of ICT has produced spillover effects in the rest of the economy. Although a more formal analysis of the impact of ICT use on aggregate TFP growth is beyond the scope of this paper, it is possible to obtain an initial assessment of this impact based on the growth accounting decomposition. For this purpose, Table 2 reports the contribution of ICT industries to total market economy TFP growth[16]. For the period 1992-1995, this contribution was, in annual average terms, 0.17 pp, rising to 0.19 pp in the period 1996-2000. Relative to total economy TFP growth, these contributions were 14% and 19%, respectively, which can be considered high if we take into account that the 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 translating into increases in productive efficiency for the whole economy, or, if they have, they have not been able to offset the negative effect of other determinants of total productivity.

TABLE 2
Contribution of ICT-producing sectors to the growth of TFP

	1992-1995				*1996-2000*			
	Δ TFP	*Weight in VA*	*Contribution to Δ TFP total eco. (a)*		*Δ TFP*	*Weight in VA*	*Contribution to Δ TFP total eco. (a)*	
	%	%	*p.p.*	*% (b)*	%	%	*p.p.*	*% (b)*
ICT manufacturing	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 the growth of TFP (ΔTFP) and weight in value added (VA).
(b) Relative to the growth of TFP (ΔTFP) of total market economy.
(c) Computed by adding the contributions of the 3 sectors involved.

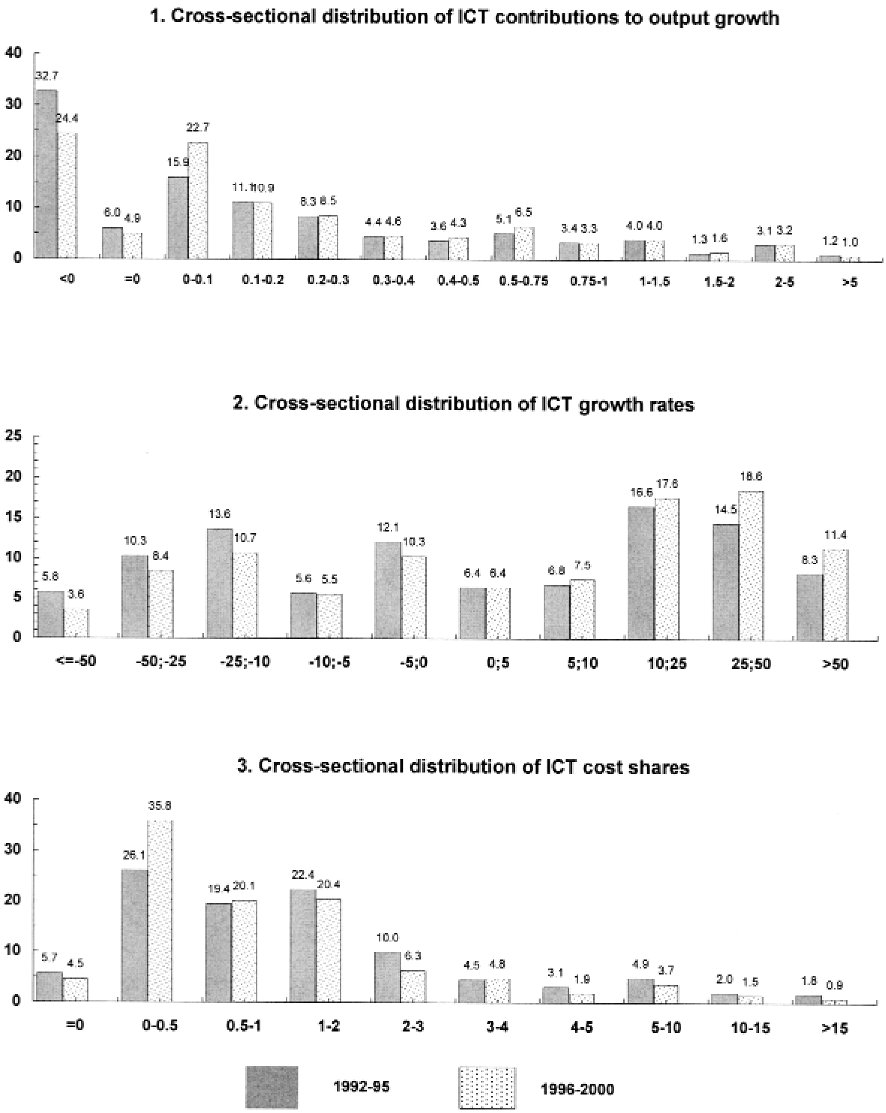
[15] For a more detailed study of ICT-producing sectors see Núñez (2001).
[16] This contribution is computed as the product of TFP growth in ICT industries and the value-added weight of ICT industries (see Schreyer, 2001).

4.3 Cross-sectional distribution of ICT contributions to value added growth

In this section we provide an overview of the results obtained at the individual level. For this purpose, Figure 6 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 behaviour. Panel 1 of Figure 6 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 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

FIGURE 6
Cross-sectional distribution of ICT capital stock variables (%)



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 1990s.

5. Conclusions

This paper examines the role played by ICT capital as an input factor and, more specifically, as a factor contributing to 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 at 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. Moreover, the results of the growth accounting decomposition are potentially sensitive to the choice of deflators for capital inputs and to the adjustment method to control for changes in the composition of capital. 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 1990s.

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 1990s. 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 what are the underlying factors driving the processes of substitution between factors or what 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 are especially useful to deal with them, since they allow the distinctive features of technology-intensive firms and of the firms displaying a high productivity growth to be identified.

Appendix A1. The database

A1.1. 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 18330 observations corresponding to 3850 firms. This information has been combined with other data sources (both sectoral and economy-wide).

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
Software 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	No. of firms	No. of firms with soft.=0	No. of firms with hard.=0	No. of firms with ICT K=0	% of firms with soft.=0	% of firms with hard.=0	% of firms with ICT=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

3. By industry

	Sample description						
				Value added sample coverage	Employment sample coverage	Employees per firm	% of firms with ICT=0
Sector	Correspondence NACE/93 (2-digit classif.)	Share in total value added (%) (2)	Total no. of obs	Annual averages			
1. Agri, Forestry & Fishery	01, 02, 05	6.8	138	0.5	1.6	415.9	27.3
2. Fuel and Power Products	10, 14, 23, 40-41	5.4	623	60.8	52.7	1040.4	5.3
3. Ferric & Non-Ferric & Metals	27-28	3.1	561	18.5	11.4	574.4	6.8
4. Non Metal. Minerals & Mineral Prod.	26	1.9	396	16.4	9.5	367.4	7.3
5. Chemical Products	24	2.3	896	34.6	28.5	383.2	5.8
6. Machinery	29-33	3.3	886	24.0	18.1	566.2	2.7
7. Transport Equipment	34-35	2.7	526	50.1	40.0	1726.8	6.2
8. Food, Beverages & Tobacco	15-16	4.2	957	21.3	14.1	505.5	6.5
9. Textiles, Cloth., Leather & Footw.	17-19	2.0	472	7.0	4.8	305.5	12.3
10. Other Manufacturing Products	20, 36	1.7	290	6.1	3.2	251.4	2.0
11. Paper and Printing Products	21-22	2.1	316	15.2	9.1	466.5	5.1
12. Rubber and Plastic Products	25	1.2	198	21.9	17.7	789.6	3.3
13. Building and Construction	45	9.9	769	8.0	6.2	800.8	10.1
14. Repair, Wholesale, Retail & host.	50-52	24.7	2078	8.0	8.9	788.0	6.8
15. Transport	60-63	7.1	786	24.4	24.0	1265.2	4.4
16. Communication Services	64	3.7	62	64.0	52.9	13591.5	2.0
17. Other Market Services	70-74	18.1	1561	5.8	6.4	553.8	12.7

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

A1.2. 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 17931 observations, corresponding to 3789 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 11515 observations corresponding to 2724 firms. Table A1.1 reports the composition of the final sample.

A1.3. 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 B. Hall (1990) and Bugamelli and Pagano (2001)-. 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:

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

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:

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

We apply this procedure to all the observations for each firm[17]. 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 Indices for Private Fixed Investment in Equipment and Software by Type").

In Appendix A2, 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 and Export Wholesale Prices.

Depreciation rates (δ_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) It 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: $f = \frac{(1-itc_t-\tau_t z_{st})}{(l-\tau_t)}$, where z represents the present value of depreciation ex-

[17] A very similar procedure is also used by the Central Balance Sheet Office of the Banco de España to construct total capital stocks. An alternative approach 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. Unfortunately, the lack of sufficiently detailed breakdowns of investment prevents us from adopting this standard approach in the construction of capital stocks.

penses, 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.

Appendix A2. 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.

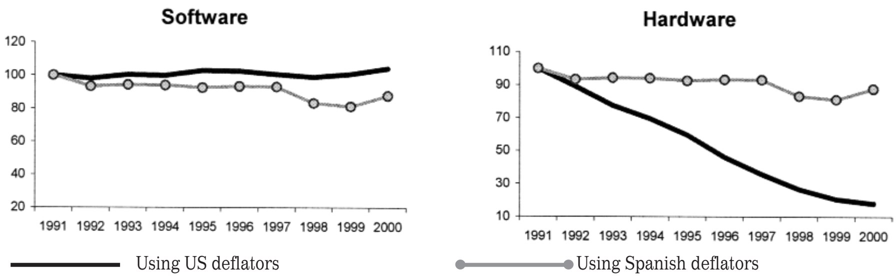
Given that, for the Spanish economy, there is no price index for ICT goods in constant quality terms[18], we apply an indirect approach –based on Schreyer (2000)– to obtain an adequate ICT deflator. Schreyer constructs the ICT price deflator for a given country in such a way that the difference between 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. 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.

An alternative approach would be the use of a set of price indices for these inputs taken directly from Spanish official statistical sources. Figure A2.1 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[19]. In the case of hardware, the index computed using US deflators shows a significantly more pronounced decline. This result clearly indicates that not taking into account the quality changes in these ICT goods introduces a sizable

[18] 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.
[19] See Appendix A1 for the detailed definition of both sets of price deflators.

bias in the estimation of their price changes and, as a consequence, in the measurement of their cost shares and their accumulation rates. 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.

FIGURE A2.1
Price deflators for investment goods



A2.1. Sensitivity of the growth accounting decomposition to the use of non-hedonic ICT price deflators

To illustrate on the importance of having constant-quality price indices for ICT inputs for the assessment of its contribution to economic growth, Table A2.1 reports the results of the growth accounting decomposition when using the Spanish ICT price index (non-hedonic).

As compared to the results reported in Table 1, the ICT contributions to both output and labour productivity growth are around 20-25% smaller. As should be expected from Figure A2.1, the changes in the results are particularly relevant in the case of hardware while software entries hardly change. The use of non-hedonic price deflator for hardware leads to an underestimation of its real growth rate and to an overestimation of its price change. Nevertheless, although the resulting ICT contributions are lower, the main conclusions hold, i.e. the ICT contributions have been significant, in particular when compared with the ICT cost shares, and they have grown during the second half of the 1990s.

TABLE A2.1

ICT contribution to value added and labor productivity growth
Results for the whole non-financial market economy (1)
(Using non-hedonic Spanish deflators for ICT capital)

	Total period	*1992-1995*	*1996-2000*
1. Labour productivity growth (2) *contribution from:*	*2.22*	*2.90*	*1,67*
2. Software	0.15	0.13	0.17
3. Hardware	0.12	0.11	0.13
4. ICT (1+2)	*0.27*	*0.24*	*0.30*
5. Rest of capital	0.77	1.37	0.30
6. Total factor productivity	1.17	1.29	1.08
7. Value-added growth rate *contribution from:*	*2.85*	*0.97*	*4.35*
8. Labour (in hours)	0.57	-1.59	2.30
9. Software	0.16	0.12	0.20
10. Hardware	0.14	0.09	0.17
11. ICT (3+4)	*0.30*	*0.21*	*0.37*
12. Rest of capital	0.80	1.04	0.61
13. Total factor productivity	1.17	1.29	1.08
Cost shares (%) (3)			
14. Software	0.73	0.64	0.80
15. Hardware	1.56	1.70	1.46
16. ICT (8+9)	2.29	2.34	2.25
17. Rest of capital	19.86	22.24	17.95
Growth rate of inputs (%) (3)			
18. Labour	0.63	-1.93	2.68
19. Software	8.50	6.93	9.76
20. Hardware	1.55	-1.72	4.16
21. ICT	5.40	2.59	7.64
22. Rest of capital	0.92	0.26	1.44

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

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Resumen

Este trabajo evalúa la contribución de los bienes y servicios relacionados con las tecnologías de la información y las comunicaciones (TIC) al crecimiento del producto y de la productividad desde el punto de vista de su utilización como factor productivo en el conjunto de la economía española. Con este fin, se aplica un enfoque metodológico convencional, que permite descomponer el crecimiento del producto y de la productividad aparente en las aportaciones de los distintos factores productivos, en una muestra de aproximadamente 1300 empresas por año durante el período 1991-2000. La utilización de datos a nivel empresarial permite atenuar los problemas de medición de los conceptos relevantes que surgen en el análisis, con información agregada, de la contribución de las nuevas tecnologías al crecimiento económico.

Palabras clave: Tecnologías de la información y las comunicaciones, contabilidad del crecimiento, cambio técnico.

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