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The importance of being IT

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Abstract

First the present article reports a growth accounting exercise for Italy and other seven OECD countries (USA, UK, Finland, Spain, France, Germany and Ireland) for the period 1980 – 2004. The exercise aims at singling out the principal growth factors among ICT / non ICT capital services, labour and total factor productivity, focusing above all on the first and last one. Then the paper compares the growth accounting results with two econometric models which use a Cobb Douglas production function, the same four factors and an ordinary least squares approach to determine the weight of each element. The comparison shows that, in the considered period, the new economy has been largely the first growth factor for all the considered countries except Italy and Spain. The estimations made show the new economy gave, in the period 1980-2004, a direct and indirect contribution to GDP growth of indicatively the 50% (as unweighed average of the considered countries).

1 - Introduction

The objective of growth accounting is to decompose the economic growth into its components. The growth accounting was first introduced by Solow (1957) and has had a revival after new more complete time series were made available. In the last ten years, growth accounting has been mainly used in the discussion about the contribution of new economy to U.S. economic growth and afterwards to European countries. First Solow (1987), Oliner and Sichel (1994) and Jorgensen and Stiroh (1995) estimated a very low contribution of the new economy to U.S. growth. After, Oliner and Sichel (2000) and Jorgenson and Stiroh (2000) indicated the information technology as very important for the U.S. growth resurgence in the late 1990s. At the moment it is widely accepted that the new economy has given a considerable contribution to US economy in last 15 years. The same methodology has been applied to European countries by Daveri (2000), Schreyer (2000) and Blanchard (2004) coming to the conclusion that a substantial part of the growth gap in 1990s between US and Europe is imputable to the European delay of IT adoption (although there are substantial differences, for example, between Italy and Spain and other countries like UK and Finland).

In this paper we consider a growth accounting exercise for Italy, US, UK, Finland, Spain,

[1]The paper was written when the author was an employee of Nokia Siemens Networks Italia. The opinions expressed in this paper are those of the author only. The company has no title and responsibility on the paper.

France, Germany and Ireland for the period 1984 – 2004. In particular, besides to the aggregate period, we envisage all the quinquenniums included in it. The framework is constituted by a production function with Hicks neutral technical progress, constant returns to scale and three production factors: the IT capital services, the non IT capital services and the labour. For sure labour and capital services certainly matter but there could be also other factors as education and government regulation. Other authors consider the role of human capital and R&D (for example Bassanini et al., 2000; Romer, 1986 and Lucas 1998)[2]. The growth accounting is made under the assumption of perfect competition among firms. The data are taken from the Groningen Growth and Development Centre (www.ggdc.net) and the measures are those recommended in OECD (2001) manual.

For the same countries and period the paper reports the estimations obtained using econometric techniques (Ordinary Least Squares) applied to the same product function. The estimations are gained with and without the intercept parameter. In the second case the variation of the total factor productivity (TFP) is limited in the time; in the first case the TFP variation is free to have average values far from zero. In other words, in the second case, the Solow residual is minimized and, in the first case, it has a component (the intercept) different from zero and an error (with zero average) minimized by the ordinary least squares[3]. In Hulten (2001) and Mahadevan (2003) you can find a complete biography about total factor productivity and Solow residual. The merger of econometric techniques and growth accounting has been used by Denny et al. (1981), and Mankiv et all. (1992) is a known paper that used econometric regression in a cross country approach. Also for the econometric method the input data are taken from Groningen Growth and Development Centre.

The aim is to single out the principal causes of growth among the non IT capital services, the labour, the IT capital services and the total factor productivity with a particular focus on the last two components. In particular the growth accounting model gives the basis for the analysis, the model without intercept helps to estimate the part of the IT production accounted in the total factor productivity and the model with intercept assists to test the likelihood of the obtained results.

The paper estimates that the new economy, in the period 1980-2004, was the engine not only for countries like USA and UK (+1.31 and +1.59% of GDP, respectively) but also for France and Germany (+1.16% and +1.06% of GDP). Countries like Finland and Ireland have almost totally founded their huge economic growth on new economy.

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[2] More precisely the model used in the present paper is neoclassical and supposes the innovation is an exogenous process. This implies the investments in R&D and education have no direct effect on the economic growth. Abandoning this supposition leads to the new growth theory (or endogenous growth) where innovation is endogenous to the system and is considered a form of capital accumulation. Some important endogenous models are also reported in Barro (1990) and Lucas (1998).

[3] For a more formal description see section 2.

Only Italy and Spain, among the considered countries, seem not to have seized the great advantages of this possibility.

Section 2 briefly examines the methods used for the estimations: the growth accounting framework and the econometric model using the ordinary least squares for the determination of the parameters. Section 3 presents the results separately obtained with the two methods and those obtained with a combined analysis. The focus is on the differences among countries, in the time and on the importance of the total factor productivity and of the new economy. The paper concludes in section 4.

2 – Method

The initial framework is essentially taken form Solow (1957). We suppose a Hick neutral aggregate product function of the form:

$$Y(t) = A(t)F(K_1(t), K_2(t), L(t)) \qquad [1].$$

Where $Y(t)$ is the GDP, $A(t)$ is the Hick neutral productivity, $K_1(t)$ the IT capital services, $K_2(t)$ the non IT capital services and $L(t)$ the labor expressed in hours[4]. In this neoclassical form of product function A(t) represents, as output per unit input, also the Total Factor Productivity (TFP). Sometimes A(t) is referred as technical change although it is acknowledged the TFP and the technological progress may be not synonymous (see for example Abramovitz, 1956 and Denison, 1967). Deriving (1) respect to time and rearranging some factors we can write:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha(t)\frac{\dot{K}_1}{K_1} + \beta(t)\frac{\dot{K}_2}{K_2} + \gamma(t)\frac{\dot{L}}{L}; \quad \alpha(t) = \frac{AK_1}{Y}\frac{\partial F}{\partial K_1}; \quad \beta(t) = \frac{AK_2}{Y}\frac{\partial F}{\partial K_2}; \quad \gamma(t) = \frac{AL}{Y}\frac{\partial F}{\partial L} \qquad [2]$$

Supposing the returns to scale constant it is possible to demonstrate $\alpha(t) + \beta(t) + \gamma(t) = 1$. The following term represents the residual growth rate not explained by input factors change and is called Solow residual:

$$\Re = \frac{\dot{Y}}{Y} - \alpha(t)\frac{\dot{K}_1}{K_1} - \beta(t)\frac{\dot{K}_2}{K_2} - \gamma(t)\frac{\dot{L}}{L} = \frac{\dot{A}}{A} \qquad [3]$$

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[4] In the practical application, the data used for K_1, K_2 and L and are taken from the Timmer et all. (2003). See also OECD (2001) and Javala (2002) about how the measures are done. Variable K_1 includes the information technology equipment, the communication equipment and the software; K_2 the other capital assets like non ICT equipment, the transportation equipment and the non residential structures.

From Equation [2] Solow residual is equal to the relative growth rate of Hick neutral parameter; in reality the Solow residual can be considered as a “measure of our ignorance” as stated by Abramovitz (1956). It can incorporate many components some wished (like technical and organizational change) other unwanted (like measure errors, wrong model specifications and aggregation bias). Equation [2] is used more for theory than for practical use. For applications the discrete version is preferred:

$$\ln\frac{Y(t)}{Y(t-1)}=\ln\frac{A(t)}{A(t-1)}+\alpha(t)\ln\frac{K_1(t)}{K_1(t-1)}+\beta(t)\ln\frac{K_2(t)}{K_2(t-1)}+\gamma(t)\ln\frac{L(t)}{L(t-1)};\quad \alpha+\beta+\gamma=1$$
[4]

To obtain the [4] from [3] it is assumed[5]:

$$\frac{dQ}{dt}\frac{1}{Q}\cong\ln\frac{Q(t)}{Q(t-1)},\quad Q=Y,A,K_1,K_2,L;\quad \eta(t)\cong\eta(t-1),\quad \eta=\alpha,\beta,\gamma \qquad .$$

Equation [4] is the starting point for both growth accounting and econometric analyses.

2.1 – *Growth accounting framework*

The growth accounting framework imposes also the hypothesis of perfect competition. Under this assumption factors are paid their marginal products. Equation [4] can be written as:

$$\ln\frac{A(t)}{A(t-1)}=\ln\frac{Y(t)}{Y(t-1)}-\frac{r_1K_1}{Y}\ln\frac{K_1(t)}{K_1(t-1)}-\frac{r_2K_2}{Y}\ln\frac{K_2(t)}{K_2(t-1)}-\frac{wL}{Y}\ln\frac{L(t)}{L(t-1)} \qquad [5].$$

Where r_1 is the rental rate of IT capital, r_2 the rental rate of non IT capital and w the labour wage. The terms $\frac{r_1K_1}{Y}$, $\frac{r_2K_2}{Y}$ and $\frac{wL}{Y}$ are the shares in GDP of IT capital, non IT capital and labour respectively[6]. These data can be easily found in the national statistics of most countries. Equation [5] allows to calculate Solow residual in the discrete form and to decompose the growth in four components: the three production factors and the total factor productivity.

Growth accounting has its weaknesses. One major problem is technical progress is often incorporated in capital goods and this makes difficult to separate innovation from capital accumula-

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[5] $\frac{dQ}{dt}\frac{1}{Q}\cong\frac{Q(t)-Q(t-1)}{Q(t-1)}=\frac{Q(t)}{Q(t-1)}-1\cong\ln\frac{Q(t)}{Q(t-1)}$ with the last passage based on $\lim_{Q\to 0}\frac{\ln(1+Q)}{Q}=1$.

[6] It is valid the relation $\frac{r_1K_1}{Y}+\frac{r_2K_2}{Y}+\frac{wL}{Y}=1$ because of the hypothesis of constant returns to scale.

tion (above all IT capital accumulation). Another problem is the product function considers only physical capital and not the investments in education and human. These aspects lead to overestimating TFP and underestimating capital. The third point is that decomposing economic growth in its components implies they are independent[7]. In many cases this is far from truth as the hypotheses of perfect competition and constant returns to scale.

2.2 – *Econometric framework*

The econometric model stems from Equation [4] removing the assumption of perfect competition and considering the parameters α, β and γ independent respect to the time and determinable by a multiple regression approach. Equation [4] can be written as:

$$\ln\frac{\frac{Y(t)}{Y(t-1)}}{\frac{L(t)}{L(t-1)}} = a_0 + \alpha \ln\frac{\frac{K_1(t)}{K_1(t-1)}}{\frac{L(t)}{L(t-1)}} + \beta \ln\frac{\frac{K_2(t)}{K_2(t-1)}}{\frac{L(t)}{L(t-1)}} + \varepsilon(t); \qquad \ln\frac{A(t)}{A(t-1)} = a_o + \varepsilon(t); \qquad E(\varepsilon)=0 \qquad [5].$$

In this form the parameters α and β ($\gamma = 1-\alpha-\beta$) can be determined using an Ordinary Least Squares method (OLS method)[8]. The determination of the parameters can be done in two ways. In the first one, the intercept a_0 is set to zero in order to minimize the Solow residual; in the second one a_0 is determined by the regression. In the last approach the variation of Solow residual is minimized around its average. In any case the parameters fixing is country specific (different α, β and γ for different countries).

We will use the model without intercept in order to estimate the part of residual TFP that can be likely attributed to the IT production (technical change embodied in IT capital). The model with intercept will be utilized as verification of the coherence of the data found with the growth accounting method and with the econometric model without intercept.

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[7] Solow assumed that labor and technology were exogenous (determined outside the model) and that investments are a constant fraction of output.

[8] Fixing α β and γ with the OLS method means to impose the conditions $\frac{\partial F}{\partial K_1} = \frac{\alpha}{K_1}F$, $\frac{\partial F}{\partial K_2} = \frac{\beta}{K_2}F$ and $\frac{\partial F}{\partial L} = \frac{\gamma}{L}F$. This is equivalent to impose from the beginning a Cobb Douglas product function of the form $Y(t) = AK_1^{\alpha}K_2^{\beta}L^{\gamma}$ instead of the more general $Y(t) = AF(K_1, K_2, L)$.

The econometric framework has its weaknesses too. The ordinary least squares are based on assumptions like average of errors equal to zero and independence of errors not easy to be verified. Besides, the productivity factors are not strictly independent among them and from the output (GDP).

This can lead to simultaneous equation bias and to questioning the robustness of the model. Another crucial point is that the number of observations must be considerably greater than the numbers of variables. It is also the case to remember that correlation does not necessarily imply a relation of cause and effect.

3 – Results

As already mentioned we considered seven European countries and the USA. The analysis covers 25 years from 1980 to 2004. In particular, for the growth accounting framework, we took five quinquennia: 1980-85, 1985-90, 1990-95, 1995-00 and 2000-04. The growth accounting results, for these periods, are reported in appendix Table 3, 4 and 5. A five year period is reasonable for the growth accounting technique but is too short for an econometric analysis. For the econometric framework we considered the entire period 1980-2004 and the period from 1995 to 2004 which should be more impacted by the new economy. For the mentioned aggregate periods the results are reported in appendix Table 7 and 8 (econometric model without and with intercept respectively). The growth accounting outputs for the same aggregate periods are listed in appendix Table 6.

Appendix Table 3, 4 and 5 show that the total factor productivity, or better its relative variation respect to the previous year $\Re$ (called Solow residual and indicated in the tables for simplicity with the label TFP), is the principal component of almost all the countries and periods.

There are some exceptions like the United States of America (quinquennia 80-85, 85-90 and 90-95) and Italy and Spain (periods 95-2000 and 2000-2004) but, generally speaking, the variation of the total factor productivity is accountable on average (respect to all countries) for almost the 40% of the entire growth (see for example the periods 85-90, 95-2000 and 2000-2004).

Although the average indicates the importance of total factor productivity there are significant differences among the considered countries. For example, in the period 1980 – 2004, Italy had a TFP contribution to GDP growth of +0.42% against the +3.09% of Ireland and the +1.84% of Finland (appendix Table 6).

In the same table the difference among countries is also greater in the period 1995-2004 where we can find a TFP contribution to GDP of about -0.40% for Italy and Spain against the +3.48% of Ireland and the +2.79 of Finland.

The TFP differences in the time lack of homogeneity too. USA shows, in the five quinquennia, a monotonic growth bringing the relative growth of TFP from +0.6% (period 1980-85) to +1.74% (period 2000-2004), instead Italy (likely Spain) exhibits a monotonic decrease from +0.89 to -1.19 in the same periods (see appendix Table 3, 4 and 5).

In the period 1980-2004 the labor contribution is near the zero in almost all the considered European countries (except Spain and Ireland with a modest +0.6%). Already Dougherty and Jorgenson (1996) found that the labour contribution to growth has been negative for Italy, France and Spain in the period 1960-1989. On the other side USA had a labour contribution of +0.95% (1980-2004) confirming a major creation of employment respect to European countries.

The contribution of non IT capital is more stable among countries respect to the other factors. It has an unweighed average of about +0,7% (appendix Table 6, period 1980-2004) and the variability among countries is not as great as for the total factor productivity. The variability in the time of the unweighed average among countries is low too (standard deviation of +0.84 in the 1995-2000 and of +0.76 in the 2000-2004).

As already mentioned in the introduction, the contribution of the new economy to GDP growth has been highly discussed in the last fifteen years. Appendix Table 6 shows that the USA high growth has been greatly boosted by the information and communication technology. In the period 1995-2004 the IT capital gave a contribution to USA GDP growth of +0.86% (second only to the TFP contribution). The datum is also confirmed in the extended period 1980-2004 with a +0.79%. In other words the new economy has been a fundamental engine of U.S. economic growth. With a less extend[9] this contribution was high also for UK, Finland and Ireland principally in the period 1995-2000. In other countries like Spain, Italy, France and Germany the new economy contribution to growth is less evident.

The considered European countries show, in other terms, a non homogenous behavior: in the period 1995-2004 Spain, Italy, France and Germany had an information technology contribution of about +0.35%; on the other hand UK, Finland and Ireland had, in the same period, a IT contribution of more than +0.6%. The behavior is surely inhomogeneous but the variability inter countries is lower respect to the other components (for example the standard deviation divided the average is 0.3% for IT K against a 1.2% for TFP in the period 1995-2004). It is important to underline the period 2000-2004 exhibited a big reduction in the attribution of economic growth to the new economy. For example, respect to the previous quinquemnium, the IT contribution passes from +1.12 to +0.54 for USA and from +0.98 to +0.32 for UK. The other countries show a similar trend. This element points out the great dependence of IT contribution on the time. Generally speaking from 1980 it grew until the end of the millennium but dropped in the subsequent four

[9] USA shows a dominance of IT contribution on all the countries and period (Tables 1, 2, 3, 4).

years. For this reason the more stable data are probably those taken from the aggregate period 1980-2004: USA with a remarkable IT contribution of +0.79%, UK with +0.53, Finland with +0.48% and Germany with +0.43%[10].

3.1 – Results: a *particular focus on TFP and IT capital*

The model used in the growth accounting framework is based on a process oriented view of technical change, something associated to the way the inputs are transformed into outputs. There is no reference to the improvements in the quality of products. As already partially mentioned the technical change embodied in the products is one major problem of the growth accounting technique and it makes difficult to separate capital accumulation from TFP residual. Last years have seen the fall of the price of many information technology capital goods, not mainly because we are able to produce more output with the same inputs, but because we are able to achieve a better quality of capital goods. This may have implied a systematic understatement of IT capital input[11]. This approach is often referred as capital-embodied technical change and implies that different vintages of IT capital (with the same price) may have different degree of marginal productivity. In other words, embodied technical change (above all in IT capital) may have considerably contributed to TFP residual in the growth accounting exercise[12]. The results of the econometric model without intercept can be partially interpreted accordingly to this point of view. In the econometric model without intercept, abandoning the hypothesis of perfect competition, the total Solow residual ("the measure of our ignorance") is minimised with an OLS method. This approach permits to have a rough estimation of the contribution of the IT capital to total factor productivity because part of TFP is redistributed to the input factors[13].

The results of the econometric model without intercept are reported in appendix Table 7. It is possible to see the TFP is sensibly reduced and attributed principally to the IT capital. Italy and Spain are exceptions: for these countries the TFP is mainly accounted to the non information and technology capital. For all the other countries the IT contribution is highly augmented mainly due to the reduction of the TFP component.

In Table 1 the IT capital contribution to TFP is reported for the period 1980-2004 (deducible from appendix Table 7 and 6). For USA the embodied IT capital is estimated to account for about

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[10] These data have the defect that in the in the 1980th the new economy was at down and its contribution is so underestimated.

[11] See for example Gordon (1990) and Violante and Cummins (2002).

[12] For some estimations of the contribution of embodiment to TFP in USA see Hulten (1992), Wolf (1996) or Greenwood et. al. (1997).

[13] This approach, of course, incorporates the weaknesses of the econometric models: the redistribution of "exceeding" TFP is made among prearranged factors and on a basis of correlation among data of the same year and not on a basis of a necessary relation of cause and effect.

the 57% of the aggregate TFP. This data is roughly in line with the 58% found by Greenwood et. al. (1997) (always for USA but in the period 1954-1990 and calculated with an other method). Another similar data is reported by Timmer et all. (2003, Table 13): 55% for USA in the period 1996-2001. The comparison of these different data can be only indicative because the periods are different and the hypothesizes are not perfectly coincident[14]. In any case the U.S. IT capital contribution to TFP is a fundamental component accounting for a considerable percentage of GDP growth. For the other considered European countries the data are inhomogeneous. The information technology contribution to GDP growth as part of TFP passes from the 0.04% of Italy to the 1.91% of Ireland with the intermediate values of 0.64% and 0.86% for Germany and France respectively. We can approximately say there are three groups of European countries: Finland, Ireland and UK with a high IT capital contribution to GDP growth as part of TFP, France and Germany with a medium contribution and Italy and Spain with a low contribution. The unweighed average of considered European countries, for what concerns the annual IT capital contribution to aggregate TFP, is 0.93% (66% of the aggregate unweighed TFP). Timmer et all. (2003), in the period 1996-2001, reports an EU's IT capital contribution of 59% of the total TFP (this datum is weighted on the relative importance of singles countries). In the last column of Table 1 the sums of the direct IT capital contribution to GDP growth and of the contribution of IT capital to the aggregate TFP growth are listed. Both Finland and Ireland show a high 2.23% followed by UK with a 1.59% and by USA with 1.31%. Italy and Spain are entitled of 0.42% and 0.63% respectively.

Table 1 – IT contribution to total factor productivity. Period 1980-2004.

	TFP % of contribution to GDP growth	IT K % of contribution to GDP growth as part of TFP	IT K contribution to Total TFP (%)	Direct IT K % of contribution to GDP growth	Sum IT K contributions (%)
Italy	0.42	0.04	9.64	0.38	0.42
Spain	0.86	0.30	34.60	0.33	0.63
USA	0.91	0.52	57.45	0.79	1.31
Finland	1.84	1.74	94.86	0.48	2.23
Ireland	3.09	1.91	61.68	0.33	2.23
UK	1.31	1.06	80.60	0.53	1.59
France	0.96	0.86	89.83	0.29	1.16
Germany	1.41	0.64	45.25	0.43	1.06

In Table 2 you can see the amplitude of the total IT contribution to GDP growth. For all the countries except Italy and Spain it has been largely the first growth factor. For Italy and Spain the

[14] For Timmer et all. (2003) the estimation is made with Domar weights.

first growth factor has been the non IT capital. Also here it is possible to roughly see three groups of countries. The first one, with high total IT contribution, is formed by Finland, Ireland, UK and US; the second, with medium IT contribution by France and Germany and the third, with low IT contribution, by Italy and Spain.

Table 2 shows also that the new economy has been, in the period 1980-2004, the economic growth engine not only for USA and UK, but also for France and Germany. Countries like Finland and Ireland have founded their big economic growth almost totally on the new economy. Only Italy and Spain, among the considered countries, seem not to have taken great advantages from this new possibility.

Table 2 – GDP annual growth average and its decomposition into IT related and not related IT components: period 1980-2004.

	GDP growth (%)	Total IT K % of contribution (direct on GDP and indirect on TFP)	Non IT K (%)	Other TFP (%)	Labour (%)
Italy	1.73	0.42	0.77	0.38	0.16
Spain	2.85	0.63	0.98	0.56	0.68
USA	3.21	1.31	0.56	0.39	0.95
Finland	2.38	2.23	0.34	0.09	-0.28
Ireland	5.47	2.23	1.42	1.18	0.63
UK	2.60	1.59	0.62	0.25	0.14
France	2.00	1.16	0.96	0.10	-0.22
Germany	1.77	1.06	0.37	0.77	-0.43

In order to have a confirmation of the method used to deduce Table 1 and 2 we utilized also the results of the econometric model with intercept. With this model, instead of the Solow residual, its variability, around a trend determined with the OLS method, is minimized. The results of this model are reported in appendix Table 8.

This table illustrates that the contribution of labour and not IT capital, in the period 1980-2004, are rather similar compared to the results of the growth accounting model and of the econometric model without intercept. What is clearly different is the contribution of IT capital and total factor productivity.

This is due to the fact they are strongly correlated. In fact, looking at appendix Table 10, it is possibly to see that the sum of the contribution of IT capital and TFP are rather similar for all the countries and for all the three models because of the fact the TFP contains a high part attributable to the IT production.

Where the sum is dissimilar (Italy, Spain and Germany for the growth accounting model) it is because the "other TFP" are relative high and the sum column of the growth accounting model contains also the "other TFP" component.

In appendix Table 9 you can find the determination index R^2 and the total error $\sum \varepsilon^2$ for both the econometric logarithmic models (given by the Equation [5]) and both the periods 1980-2004 and 1995-2004. The determination index is acceptable for all the countries in the period 1980-2004 but has some low values in the period 1995-2004.

4 – Conclusion

The paper considers a growth accounting exercise for Italy, France, Germany, Spain, Finland, Ireland, UK and USA in the period 1980-2004 integrating the results with the those obtained by an econometric model aimed, above all, at singling out an estimation of IT production to the total factor productivity. The results of the pure growth accounting model (appendix Table 3, 4, 5, and 6) are principally:

- The total factor productivity is, with little exceptions, the principal GDP growth component. Although the unweighed average (+1.35 in the 1980-2004) indicates its significance there are huge differences among countries and in the time.
- The labour contribution in European countries is near to zero and clearly in contrast with the USA +0.95% datum (1980-2004).
- The contribution of Non IT Capital shows a high unweighed average of +0.75% (1980-2004) and has a lower variability, among countries, respect to the TFP contribution.
- USA shows the biggest IT capital contribution with a +0.79 in the period 1980-2004. The IT capital contribution is also high in UK, Finland and Ireland but principally in the period 1995-2004 (on average about +0.6%). The other considered European countries show a less evident IT capital contribution with a +0.35% on average among France, Germany, Spain and Italy. The IT capital contribution variability among the considered countries is evident (but lower than the variability of the other components). The variability in the time is huge.

Abandoning the hypothesis of perfect competition we used the econometric model given by Equation [5] to estimate the contribution of IT production to the total factor productivity. The results are presented in Table 1, 2 and 7 (period 1980-2004). The major highlights are:

- In appendix Table 7 the TFP (seen here as the total factor productivity not depending by any production factors) is sensibly reduced. The great part of the TFP reduction is attributed to IT capital with the exceptions of Spain and Italy.

- Table 1 reports the contribution of IT capital to TFP: high for USA, Finland, Ireland and UK; medium for France and Germany; low for Italy and Spain.
- The total information technology contribution (sum of the direct IT capital contribution to GDP growth and of IT production contribution to TFP) is, by large, the first growth factor for all the considered countries except for Italy and Spain (Table 2). The new economy, in the period 1980-2004, has been the growth engine, not only for USA and UK, but also for Germany and France. Finland and Ireland have founded their economic growth almost exclusively on the new economy. Approximately Finland, Ireland, UK and USA (+2.23%, +2.23%, +1.59%, and +1.31% respectively) show a high contribution of new economy; France and Germany a medium supply (+1.16% and +1.06%); and Italy and Spain a low grant (+0.42% and +0.63%).

In other words, in the period 1980-2004, the contribution of the new economy is fundamental in almost all the considered countries. The relevance of this aspect is particular due to the part of the new economy counted inside the total factor productivity (indicated in Table 1 as "IT K % of contribution to GDP growth as part of TFP"). The relevance of the "Direct IT K % of contribution to GDP growth" is numerically lower but nevertheless important. The variability among countries is particularly due to the part of the new economy conglomerated in the TFP (unweighed standard deviation of 0.44% against 0.03% of the direct IT contribution). This seems to support the thesis that it is particularly important how the information and technology is utilized, inserted and exploited in the economic context of the determined country and not only the amount of done IT investments.

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Appendix

Table 3 – Results of the growth accounting model: annual average of GDP growth and its decomposition into IT capital, non IT capital, labour and TFP. Periods 1980-1985 and 1985-1990. All data are in percentage points.

	(a)[15]	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	1980-85					**1985-90**				
	GDP	IT K	Non IT K	L	TFP	GDP	IT K	Non IT K	L	TFP
Italy	1.53	0.29	0.66	-0.31	0.89	2.82	0.44	0.88	0.65	0.85
Spain	1.39	0.24	0.49	-2.50	3.17	4.71	0.47	1.25	2.22	0.76
USA	3.30	1.01	0.59	1.09	0.60	3.32	0.65	0.63	1.39	0.65
Finland	2.93	0.39	0.86	0.33	1.35	3.19	0.47	1.05	0.05	1.63
Ireland	2.21	0.30	1.00	-1.01	1.91	5.12	0.01	0.67	0.81	3.63
UK	2.08	0.38	0.60	-0.38	1.48	3.47	0.49	1.05	1.04	0.89
France	1.50	0.31	0.97	-1.36	1.58	3.29	0.32	1.27	0.51	1.19
Germany	0.97	0.58	0.37	-0.75	0.77	3.48	0.48	0.45	0.19	2.36

[15] Columns in the tables are indicated with the labels: (a), (b), (c), (d) and (e). Column (a) contains the GDP growth, column (b) the GDP growth attributable to information technology capital services (including telecommunication capital services). The column (c) contains the GDP growth imputable to not technological capital services, column (d) the contribution of labor and column (e) contains the GDP growth due to the variation of the total factor productivity.

Table 4 – Results of the growth accounting model: annual average of GDP growth and its decomposition into IT capital, non IT capital, labour and TFP.
Periods 1990-1995 and 1995-2000. All data are in percentage points.

	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	1990-95					**1995-2000**				
	GDP	IT K	Non IT K	L	TFP	GDP	IT K	Non IT K	L	TFP
Italy	1.20	0.28	0.61	-0.69	1.01	2.04	0.50	0.84	0.45	0.24
Spain	1.51	0.23	0.93	-0.60	0.94	4.05	0.44	1.09	2.88	-0.35
USA	2.53	0.59	0.45	0.93	0.56	4.33	1.12	0.68	1.37	1.16
Finland	-1.46	0.39	-0.26	-2.44	0.86	5.04	0.64	-0.06	1.06	3.40
Ireland	4.76	0.17	0.82	0.70	3.06	10.19	0.78	2.53	2.21	4.67
UK	1.71	0.43	0.52	-0.86	1.61	3.36	0.98	0.58	0.73	1.08
France	0.97	0.21	0.99	-0.24	0.01	2.77	0.40	0.75	0.16	1.47
Germany	1.92	0.30	0.57	-0.80	1.86	1.74	0.49	0.31	-0.35	1.29

Table 5 – Results of the growth accounting model: annual average of GDP growth and its decomposition into IT capital, non IT capital, labour and TFP. Period 2000-2004. All data are in percentage points.

	(a)	(b)	(c)	(d)	(e)
	2000-2004				
	GDP	IT K	Non IT K	L	TFP
Italy	0.88	0.39	0.88	0.80	-1.19
Spain	2.56	0.27	1.19	1.64	-0.55
USA	2.41	0.54	0.42	-0.29	1.74
Finland	2.29	0.53	0.07	-0.34	2.03
Ireland	5.17	0.39	2.28	0.47	2.03
UK	2.35	0.32	0.29	0.21	1.53
France	1.36	0.22	0.81	-0.13	0.45
Germany	0.51	0.26	0.09	-0.46	0.62

Table 6 – Results of the growth accounting model: annual average of GDP growth and its decomposition into IT capital, non IT capital, labour and TFP contribution. Periods 1980-1985 and 1985-1990. All data are in percentage points.

	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	1980-2004					**1995-2004**				
	GDP	IT K	Non IT K	L	TFP	GDP	IT K	Non IT K	L	TFP
Italy	1.73	0.38	0.77	0.16	0.42	1.52	0.45	0.86	0.61	-0.40
Spain	2.85	0.33	0.98	0.68	0.86	3.39	0.36	1.14	2.33	-0.44
USA	3.21	0.79	0.56	0.95	0.91	3.47	0.86	0.57	0.63	1.42
Finland	2.38	0.48	0.34	-0.28	1.84	3.81	0.59	0.00	0.43	2.79
Ireland	5.47	0.33	1.42	0.63	3.09	7.93	0.61	2.42	1.43	3.48
UK	2.60	0.53	0.62	0.14	1.31	2.91	0.68	0.45	0.50	1.28
France	2.00	0.29	0.96	-0.22	0.96	2.14	0.32	0.78	0.03	1.02
Germany	1.77	0.43	0.37	-0.43	1.41	1.19	0.38	0.21	-0.40	0.99

Table 7 – Results of the Econometric model without intercept: GDP annual growth average and its decomposition into IT capital, non IT capital, labour and TFP contribution. Periods 1980-2004 and 1995-2004. All data are in percentage points.

	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	1980-2004					**1995-2004**				
	GDP	IT K	Non IT K	L	TFP	GDP	IT K	Non IT K	L	TFP
Italy	1.73	0.45	1.25	0.13	-0.10	1.52	0.06	1.09	0.55	-0.17
Spain	2.85	0.75	1.75	0.55	-0.21	3.39	-0.19	1.17	2.43	-0.03
USA	3.21	1.84	0.04	1.15	0.18	3.47	1.89	0.87	0.45	0.27
Finland	2.38	2.81	-0.18	-0.35	0.09	3.81	3.38	-0.01	0.24	0.20
Ireland	5.47	2.34	1.59	0.52	1.02	7.93	3.34	4.10	0.40	0.10
UK	2.60	1.59	0.64	0.14	0.24	2.91	0.62	2.40	-0.35	0.24
France	2.00	1.16	1.08	-0.17	-0.07	2.14	1.23	1.04	0.02	-0.15
Germany	1.77	1.06	0.81	-0.21	0.11	1.19	1.14	0.28	-0.30	0.06

Table 8 – Results of the Econometric model with intercept: annual average of GDP growth and its decomposition into IT capital, non IT capital, labour and TFP contribution. Periods 1980-2004 and 1995-2004. All data are in percentage points.

	(a)	(b)	(c)	(d)	(e)	(a)	(b)	(c)	(d)	(e)
	1980-2004					**1995-2004**				
	GDP	IT K	Non IT K	L	TFP	GDP	IT K	Non IT K	L	TFP
Italy	1.73	1.68	1.34	0.09	-1.38	1.52	3.36	0.20	0.64	-2.68
Spain	2.85	2.13	1.73	0.45	-1.46	3.39	0.61	1.66	1.79	-0.67
USA	3.21	0.26	0.01	1.32	1.62	3.47	-1.49	-0.04	1.01	3.99
Finland	2.38	0.38	-0.05	-0.38	2.43	3.81	-0.02	-0.01	0.32	3.52
Ireland	5.47	0.88	0.31	0.98	3.30	7.93	2.25	2.42	1.24	2.03
UK	2.60	-0.60	0.40	0.19	2.60	2.91	-0.49	1.40	0.14	1.86
France	2.00	1.62	1.21	-0.15	-0.69	2.14	2.04	1.60	0.01	-1.51
Germany	1.77	0.30	0.62	-0.33	1.17	1.19	0.83	0.27	-0.33	0.43

Table 9- The determination index R^2 and the total error $\sum \varepsilon^2$ for both the logarithmic econometric models given by Equation [5]. Periods 1980-2004 and 1995-2004.

	(f)	(g)	(f)	(g)	(f)	(g)	(f)	(g)
	OLS without intercept				**OLS with intercept**			
	1980-2004		**1995-2004**		**1980-2004**		**1995-2004**	
	sum(ε^2)	R^2	sum(ε^2)	R^2	Sum(ε^2)	R^2	sum(ε^2)	R^2
Italy	0.003615461	0.66	0.000774549	0.40	0.003287405	0.69	0.000372442	0.71
Spain	0.002015936	0.87	0.000181908	0.38	0.001310821	0.92	0.000166273	0.43
USA	0.00343295	0.68	0.001061686	0.82	0.00275714	0.75	0.000136976	0.98
Finland	0.007181978	0.71	0.003124517	0.74	0.006644763	0.73	0.002519007	0.79
Ireland	0.018154378	0.67	0.001947903	0.93	0.010534027	0.81	0.001784405	0.93
UK	0.004426382	0.73	0.000625541	0.86	0.002979674	0.82	0.000231127	0.95
France	0.002573794	0.85	0.000759126	0.87	0.00246564	0.86	0.000556626	0.90
Germany	0.005660258	0.71	0.000340095	0.90	0.005365444	0.73	0.000318275	0.91

Table 10 – Comparison of the three models for what concerns the sum of the IT capital contribution and of the total factor productivity. Period 1980-2004.

	(b)	(e)	(b) + (e)	(b)	(e)	(b) + (e)	(b)	(e)	(b) + (e)
	1980-2004								
	Growth Accounting			**OLS without intercept**			**OLS with intercept**		
	IT K	TFP	Sum	IT K	TFP	Sum	IT K	TFP	Sum
Italy	0.38	0.42	0.80	0.45	-0.10	0.35	1.68	-1.38	0.30
Spain	0.33	0.86	1.19	0.75	-0.21	0.55	2.13	-1.46	0.67
USA	0.79	0.91	1.70	1.84	0.18	2.02	0.26	1.62	1.88
Finland	0.48	1.84	2.32	2.81	0.09	2.91	0.38	2.43	2.80
Ireland	0.33	3.09	3.42	2.34	1.02	3.36	0.88	3.30	4.18
UK	0.53	1.31	1.84	1.59	0.24	1.83	-0.60	2.60	2.01
France	0.29	0.96	1.25	1.16	-0.07	1.09	1.62	-0.69	0.94
Germany	0.43	1.41	1.83	1.06	0.11	1.17	0.30	1.17	1.48