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ALTERNATIVE ESTIMATES OF CAPITAL INPUT IN PRODUCTIVITY MEASURES. A SENSITIVITY ANALYSIS FOR THE ITALIAN ECONOMY OVER 1980-2003.

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ABSTRACT

In this paper, we illustrate the methodology adopted by the Italian Institute of Statistics (ISTAT) to calculate capital input in productivity measure and we show some results for the Italian economy over 1980-2003. We calculate the productive capital stock, the flow of capital services provided by ICT and non-ICT capital goods and their contributions to the growth of both total capital services and capital stock. Then we estimate productive capital stocks for a detailed asset-type classification system and we report both aggregate and industry results for the Italian economy since 1980. Moreover we evaluate the impact of different assumptions on depreciation rates and rates of return in the estimate of the user cost of capital and on age-efficiency profiles in the calculation of productive capital stock. Finally, we contrast the volume index of capital services with aggregate capital stock (a measure of capital input that does not take into account the heterogeneity of marginal products of different asset types).

Our main findings are: *i*) the various measures of capital services do not differ substantially with respect to the choice of age-efficiency and age-price profiles but are more sensitive to different net rates of return; *ii*)in almost all years the volume index of capital services grows faster than aggregate capital stock and it shows a higher sensitivity to the business cycle; *iii*) in terms of ICT relative contribution to the growth of total capital services, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's were even more "ICT oriented"; *iiii*) both the growth of total capital services and ICT contribution were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.

Keywords: ICT; Capital Services; Productive Capital Stock.

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1. INTRODUCTION

The outstanding progress in Information and Communication Technology (ICT) witnessed in the past decade seems to have had a remarkable role in fostering economic growth both in developed and developing countries (Vu, 2004). However measuring and assessing the impact of ICT on economic growth is still a challenging task for most economies.

One of the fundamental step to evaluate the impact of new technologies on economic growth is to find an appropriate measure of the flow of capital services provided by ICT capital goods.

The standard neoclassical approach provides a comprehensive and consistent framework to capital measurement (OECD, 2001a and b) and allows several possibilities about the choice of different depreciation patterns, efficiency decay profiles and rate of returns. But to identify the most appropriate estimate of capital services it is necessary to evaluate how much responsive capital input is to the above different assumptions.

In this paper, we illustrate the methodology adopted by the Italian Institute of Statistics (ISTAT) to calculate capital input for productivity measure and we address the following issues: How much sensitive is the measure of capital services to different age-efficiency and age-price profiles? What is the influence of different rates of return (exogenous versus endogenous)? Do ICT and Non-ICT capital services react in a different way to the assumptions on age-efficiency and age-price profiles? And on different rates of returns? And finally, which is the contribution of ICT to the growth of capital services?

We provide some results for the Italian economy over 1980-2003.

We calculate productive capital stock, the flow of capital services provided by ICT and non-ICT capital goods and their contributions to the growth of both total capital services and capital stock. We estimate productive capital stocks for a detailed asset-type classification system and we report both aggregate and industry results for the Italian economy since 1980. Moreover we evaluate the impact of different assumptions on depreciation rates and rates of return in the estimate of the user cost of capital and on age-efficiency profiles in the calculation of productive capital stock. Finally, we contrast the volume index of capital services with aggregate capital stock (a measure of capital input that does not take into account the heterogeneity of marginal products of different asset types).

The structure of the paper is as follows. Some issues about capital service measurement are outlined in section 2, while section 3 shows the empirical results for the Italian economy in 1980-2003. Some conclusions are drawn in section 4.

2. CAPITAL SERVICES MEASUREMENT

The calculation of the contribution of capital goods to the production process requires a two-stage process (OECD, 2001b). First, it is necessary to estimate quantity and price of the services provided by each type of asset (i.e. its productive capital stock and its user cost), then to construct an aggregate measure of the productive contribution of the different type of assets (i.e. of the aggregate flow of capital services)

In this paper we adopt the standard neoclassical approach that provides a consistent and comprehensive framework to capital services measurement. As it is widely known, the neoclassical model relies on some simplifying assumptions (constant returns to scale, perfect competition and long-run equilibrium and some stringent properties of the production technology required for a consistent aggregation) that are hardly met in real world economies. Therefore, it should bear in mind that the results derived using this framework must be regarded as approximate at best (Hulten, 1990). In this paragraph we provide a brief non technical overview of neoclassical approach to capital service measurement (see Hulten, 1990, Jorgenson, 1989 and Diewert 2003 for comprehensive descriptions of both the theory and empirical issues on capital measurement).

2.1 The Productive Capital Stock and the user cost

In order to quantify the contribution of a specific type of asset to the production process it is essential to evaluate the flow of capital services generated by the asset during the accounting period. The flows of capital services are not (usually) observable; therefore they have to be measured by a proxy. The standard practice assumes that the service flows are in proportion to the productive capital stock.

For an asset whose service life is T years (i.e. an asset that remains in use in the productive process for T years), the productive capital stock is defined as a weighted sum of past investment of the last T years, where the weights reflect the efficiency decay of the asset as it ages (i.e. the fact that older assets are less productive than newer because of wear and tear).

The pattern of the quantity of capital services produced by an asset over its service life relative to the quantity produced by a new asset (i.e. the sequence of the weights used to define the productive capital stock) is referred to as the age-efficiency profile.

The estimation of the productive capital stock must deal with the fact that the actual service life for assets put in place in a given year will not be the same for all the assets.

In order to account for the heterogeneity in the service lives the usual approach is to assume that retirements follow a given distribution around the mean service life.

The user cost (or rental price) of capital is a measure of how much does it cost using one unit of the services provided by that asset. More precisely, it includes the cost for financing the purchase of the capital good, its economic depreciation, the capital gains-losses due to asset price changes and the net burden due to the tax structure for business income.

A great deal of literature originated from the seminal contributions of Jorgenson (1963) and Hall and Jorgenson (1967), has been devoted both to theoretical refinements and to empirical estimates. Jorgenson and Griliches (1967) linked user cost and capital services measurement.

For the purposes of this paper, we refer to a simplified formula of the user cost of capital that does not take into account those factors related to the tax treatment of business income:

$$u^i_t = q^i_t \, (r_t + d^i_t - g^i_t)$$

where q^i_t is the acquisition price for a new capital good, r_t is the net return on investment, d^i_t is economic depreciation rate and g^i_t measures capital gains-losses.

Since direct observations of user costs exist only for the few capital goods that are rented, the usual way to estimate u^i is imputing directly its components from observable data. In a similar way, since there is scarce empirical evidence on the efficiency decay of an asset, the age-efficiency pattern is not often estimated but rather it is assumed that it follows a specific pattern over the service life.

Age-efficiency and depreciation profiles cannot be defined independently of each other. Economic depreciation quantify the loss in value of a capital good as it ages and it is described by the sequence of relative prices for different vintages of the asset (its age-price profile). The market valuation of the stock of a capital good is measured by its net capital stock.

Economic depreciation and efficiency decay follow two (in general) different but not independent patterns over time: every specific age-efficiency pattern implies a specific age-price profile. Indeed, the price of an asset depends on the income generated by the asset and the income depends on the quantity of services and their price. Since the price of an asset depends on the discounted flow of income it will generate during its remaining lifetime, both present and future declines in productive capacity of the asset affect the change in its price from one year to the following one (and not only the change in actual efficiency due to the fact that the asset is one year older). For instance, if the efficiency decay follows the so-called one-hoss-shay pattern (no loss in efficiency until the asset is retired), there is no decline in actual efficiency for the T years during which the asset is productive. Nevertheless the age-price profile is declining over time because as time goes by the remaining asset life is shorter and the willingness to pay for it will be lower.

Full consistency between productive capital stock and user cost estimates can be obtained assuming a specific profile for the age-efficiency function and then deriving age-price profile using the relationship that expresses the price of an asset as a function of the discounted flow of its future rentals. Alternatively one can start from a measure of net capital stock and depreciation and then derive the age-efficiency profile (see Schreyer et al. 2005 for a detailed description of computational aspects of both avenues).

When productive and net capital are estimated independently, one should check that the pattern of economic depreciation implied by the age-efficiency profile be at least broadly consistent with that implied by the depreciation method used to estimate the net capital stock and consumption of fixed capital.

2.2. Aggregation Across Assets

Once we have estimated the productive stock for different types of assets, then we have to aggregate them to get a measure of the overall flow of services provided by the stocks.

The aggregation procedure is a matter of choosing both the specific index number formula by which the aggregation takes place and the weights that are used.

In the standard approach, aggregation is implemented using a changing weight index (usually the Tornqvist index) and cost-share weights for each asset type, where the cost refers to the cost of using the asset during the accounting period[i]. In other words, we deem the cost-shares in terms of user costs and not in terms of acquisition prices.

Let S^i_t be the productive stock of type i asset, u^i_t its user-cost and S the flow of total capital services. With the Tornqvist aggregation, the (logarithmic) rate of change of S is:

$$\ln\left(S_t / S_{t-1}\right) = \sum_{i=1}^{n} 0.5\left(v^i_t + v^i_{t-1}\right) \ln\left(S^i{}_t / S^i{}_{t-1}\right) \tag{5}$$

where $v^i_{t} = (u^i_t S^i_t / \Sigma_{i \in n} \; u^i_t S^i_t)$ is the cost-share of asset i in period t and *n* is the number of asset types.

The contribution of each type of capital good to the growth of overall capital services is equal to the rate of change of its real productive capital stock (that it is assumed to be equal to the rate of change of the flows of services it provides) times its share in the value of total cost for capital in that period.

Changing weight indices are preferred to fixed weights indexes because they are not affected by the substitution bias. Moreover, the Tornqvist index has the theoretically desirable property that it is an exact index for a translog structure of production (Diewert, 1976).

In general, each type of capital good has its own marginal productivity that is different from that of the other types. In other words, the increase in the flows of capital services provided by an additional unit of capital of a certain type (say structures) can be different from the raise provided by an additional unit of capital of a different type (say hardware).

Cost-share weights allow accounting for the heterogeneity in the marginal product of each type of capital good (and so for changes in the composition of aggregate capital stock). In fact, under the standard neoclassical assumptions, differences in user-cost across assets reflect differences in their marginal products. So weighting the rates of change of the n asset-specific productive capital stocks with the relative cost shares is equivalent to assign a relatively larger weight to the rates of change of the assets that have higher marginal product and it allows to account for the substitution among different types of capital goods.

Note that measures of capital input based on asset price weights, as the aggregate productive capital stock (it is immaterial that they be the simple sum of the stocks of the various types of capital goods or changing weights indexes), fail to account for changes in the composition of capital stock.

This point can be made clearer comparing the contribution of each type of capital good to the growth of overall capital services with its contribution to the growth of aggregate real productive capital stock. If the real productive capital stocks are of the fixed-weight type (as it is the case for Italian data), it is possible to construct the real aggregate capital stock by direct summation of the stocks. In this case the contribution of each type of capital good to the growth of the aggregate productive capital stock is equal to the rate of change of its productive capital stock at constant prices times its share in the aggregate productive capital stock at constant prices. Thus the rates of growth of two assets that have the same share in real capital stock, have the same weight, regardless of their actual marginal product. Put differently, it makes no difference whether firms invest in structures, cars, furniture or computers: the measure of the aggregate capital stock is not affected by its composition.

Thus a volume index of the aggregate productive stock is not a proper measure of the change in the flows of services provided by the existing stocks; rather, it is a measure (in base-year prices) of the change in the hypothetical quantity of new assets that would produce the same flow of services as the actual capital stock[ii] (Hill, 1999).

The difference between the growth rates of the cost-shares weighted Tornqvist index and the directly aggregated capital stock is usually referred to as composition effect.

The composition effect is positive (i.e. the rate of growth of the flow of capital services is higher than that of the capital stock) when the asset whose productive stock grows relatively faster are those that have the relatively higher user cost. In other words, the composition effect is positive when there is a shift in the composition of investment toward assets that provide a relatively higher flow of services per unit of capital.

2.3 ICT and Non-ICT Capital Services

In order to evaluate the impact of ICT on aggregate capital services growth, the standard growth accounting framework outlined in the previous paragraph is modified by a breakdown of the flow of capital services into ICT and non-ICT capital services.

A volume index of the flow of capital services from ICT (Non-ICT) capital goods is obtained by aggregating across productive stocks of ICT (Non-ICT) capital goods using the Tornqvist index with weights equal to the share of each asset in the value of total cost for ICT (Non-ICT) capital services.

If there are *ni* ICT-type assets and *nn* Non-ICT (with *ni*+*nn*=*n*), then the indices of ICT and Non-ICT capital services (respectively $\ln(SI_t/SI_{t-1})$ and $\ln(SN_t/SN_{t-1})$) are:

$$\ln\left(SI_t / SI_{t-1}\right) = \sum_{i=1}^{ni} 0.5\left(vi_t^i + vi_{t-1}^i\right) \ln\left(S_t^i / S_{t-1}^i\right) \tag{7}$$

where $vi_t^i = u_t^i S_t^i / \sum_{i=1}^{ni} u_t^i S_t^i$ and

$$\ln\left(SN_t / SN_{t-1}\right) = \sum_{i=1}^{nn} 0.5\left(vn_t^i + vn_{t-1}^i\right) \ln\left(S_t^i / S_{t-1}^i\right) \tag{8}$$

where $vn_t^i = u_t^i S_t^i / \sum_{i=1}^{nn} u_t^i S_t^i$

These two indexes can be used to evaluate the contribution of ICT and Non-ICT capital goods to output growth in an extended growth accounting framework. Under constant return to scale, the contribution of ICT (Non-ICT) capital goods to output growth is equal to the Tornqvist index of ICT (Non-ICT) capital services times the share of ICT (Non-ICT) income in total output.

Another point of interest is evaluating the contributions of the two components of capital services to the overall capital services growth.

The contribution of ICT (Non-ICT) capital services to aggregate capital services growth is equal to the Tornqvist index of ICT (Non-ICT) capital services times the share of ICT (Non-ICT) cost in the value of total cost for capital services. In fact we have:

$$\ln\left(S_t / S_{t-1}\right) = 0.5\left(ci_t + ci_{t-1}\right) \ln\left(SI_t / SI_{t-1}\right) + 0.5\left(cn_t + cn_{t-1}\right) \ln\left(SN_t / SN_{t-1}\right) \tag{9}$$

where $ci_t = \sum_{i=1}^{ni} u_t^i S_t^i / \sum_{i=1}^{n} u_t^i S_t^i$ and $cn_t = \sum_{i=1}^{nn} u_t^i S_t^i / \sum_{i=1}^{n} u_t^i S_t^i$

i.e. ci_t is the share of ICT capital goods in the value of total cost for capital services in period t and cn_t is the share of non-ICT capital goods.

2.4 Implementation issues

There are alternative user cost formulas that are consistent with economic theory and there is no enough empirical evidence to discriminate among them. As a consequence, empirical practice has varied concerning the choice of the age-efficiency and age-price profiles and of the net rate of return and the specification of the retirement pattern and of the capital gains term.

Capital input estimates adopted in ISTAT productivity measure relies on the following assumptions. The productive capital stock of each type of capital good is estimated assuming an age-efficiency profile concave towards the origin (i.e. efficiency falls at a rate that increases as the asset ages). The profile is derived from an hyperbolic function. The retirement pattern is a truncated normal distribution around a constant service life. The corresponding user cost is imputed as follows. The net rate of return is calculated as a weighted average of two market interest rates taken as a measure, respectively, of the cost of debt and of the opportunity cost implicit in internal sources of financing[iii] (i.e. using productivity analysis jargon, we use an exogenous rate of return). The acquisition prices for new capital goods are calculated as the ratio of investment at current prices to investment at constant prices. The depreciation rate is obtained as the ratio of consumption of fixed capital at constant prices to net capital stock at constant prices. Net capital stock and consumption of fixed capital are estimated using the straight line model of depreciation (i.e. it is assumed that the age-price profile follows a pattern of linear decline). Note that different assumptions about the age-price profile lead to different depreciation rates. The capital gains-losses term at time t is defined as a moving average of the rates of changes in the asset price in the three years priors to t. From an empirical point of view, using a moving average of asset price changes reduces the volatility in the user cost series.

In this paper we evaluate the impact on the growth of capital input of different assumptions on depreciation rates and rates of return in the estimate of the user cost of capital and on age-efficiency profiles in the calculation of productive capital stock.

The hyperbolic profile of efficiency decay is motivated by two main reasons: this pattern is considered a plausible description of the efficiency decay of many types of capital goods, and the depreciation pattern implied by this age-efficiency function is broadly consistent with the depreciation method used to estimate net capital stock and depreciation, i.e. the straight-line method (Blades, 1998, OECD 2001b).

A first alternative measure is obtained deriving directly the age-price profile from the assumed age-efficiency profile, instead of assuming a linear one. A comparison of these two measures allows us to assess if our capital input measure is consistent.

Another common choice for age-efficiency decay is the so-called geometric pattern (i.e. efficiency falls at a constant rate as the asset ages). An important result that characterizes the geometric model is that, when the maximum service life converges towards infinity, age-efficiency and age-price profile coincide. Usually it is assumed that this profile accounts both for efficiency decay and for retirements, so that no explicit retirement function is required for its implementation.

With respect to the nominal net rate of return, an alternative approach is to estimate it as an internal rate. This option is based on the assumption that the remuneration of capital services exhausts total non labour income measured from National Accounts (gross operating surplus plus an imputation for the component of gross mixed income attributed to capital). If this equality holds, given the estimates of total income and of productive capital stock and of the other components of user-cost for each asset, then net rate of return can be computed residually. This rate of return is referred to as endogenous rate.

3. Empirical Issues

This section presents a first set of results for the Italian economy in the period 1980-2003.

Both the productive capital stock and the user cost of capital have been estimated for nine types of capital goods that comprises non-residential gross fixed capital formation: machinery and equipment; furniture; hardware; communications equipment; software; road transport equipment; air, see and rail transport equipment; non-residential buildings and other intangibles and services.

However, our results must be considered as preliminary under several respects. The data used in this paper are going to be revised as a result of the ongoing benchmark revision of National Accounts that will be ended by December 2005; therefore they might be subject to revision.

A crucial point in capital services measurement is the deflation of nominal gross fixed capital formation. In this paper, we used deflators gathered from National Account data. The user cost of capital has been calculated without taking into account tax factors.

3.1. Sensitivity analysis

In this section we present a comparison between alternative measures of capital input. We tested the following hypothesis: hyperbolic age-efficiency decay and linear age-price profile (hl); hyperbolic age-efficiency decay and integrated age-price profile (hi); geometric age-efficiency and age-price profiles (gg). Moreover we consider also a non consistent measure based on the same linear decline both for the age-efficiency and age-price profiles (ll). Each of the previous assumption has been adopted in both exogenous (bi) and endogenous (en) net rate of returns measures of capital.

Table 1 reports the average annual rates of growth of the mentioned eight measures of capital services and the corresponding measures of aggregate productive capital stock.

Table 1 - Growth of Capital Services (net of residential capital).

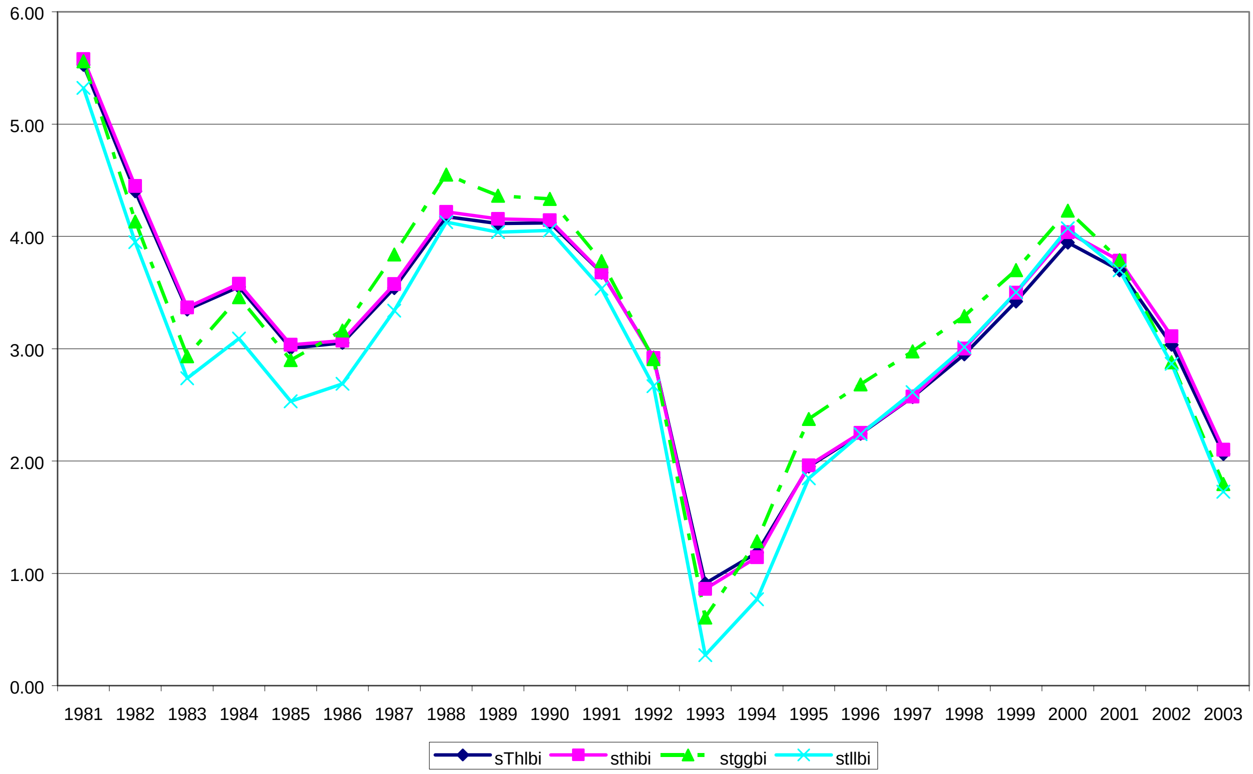
	1980-2003	1980-1985	1985-1990	1990-1995	1995-2000	2000-2003
hlbi	3.2	4.0	3.9	2.2	3.1	3.0
hlen	3.1	3.8	3.8	2.1	2.9	2.8
hibi	3.3	4.1	3.9	2.1	3.1	3.0
hien	3.2	3.9	3.9	2.1	3.0	2.9
ggbi	3.3	3.9	4.1	2.2	3.4	2.9
ggen	3.1	3.4	3.9	2.2	3.1	2.7
llbi	3.0	3.6	3.7	1.8	3.1	2.8
llen	2.8	3.2	3.5	1.8	2.8	2.6
capproh	2.7	3.2	3.3	2.1	2.4	2.4
capprog	2.7	2.8	3.3	2.2	2.6	2.4
capprol	2.5	2.7	3.1	1.8	2.4	2.3

[a] Average annual rate of growth in the period shown multiplied by 100

[b] Percentage points

Over the whole period we find that only minor differences (if any) exist between the consistent or broadly consistent measures of capital services. Capital input growth is comprised in a range between 3.1% and 3.3%. The three measures based on endogenous rate of return record a bit lower average growth than the corresponding one based on exogenous rate of growth. On the other hand, the non consistent measure (based on the same linear pattern both for efficiency decay and depreciation) grows at fairly slower rates in both cases (2.8% using endogenous rate and 3.0% adopting exogenous rate).

Chart1 - Capital service measures based on exogenous net rate of return: 1980-2003

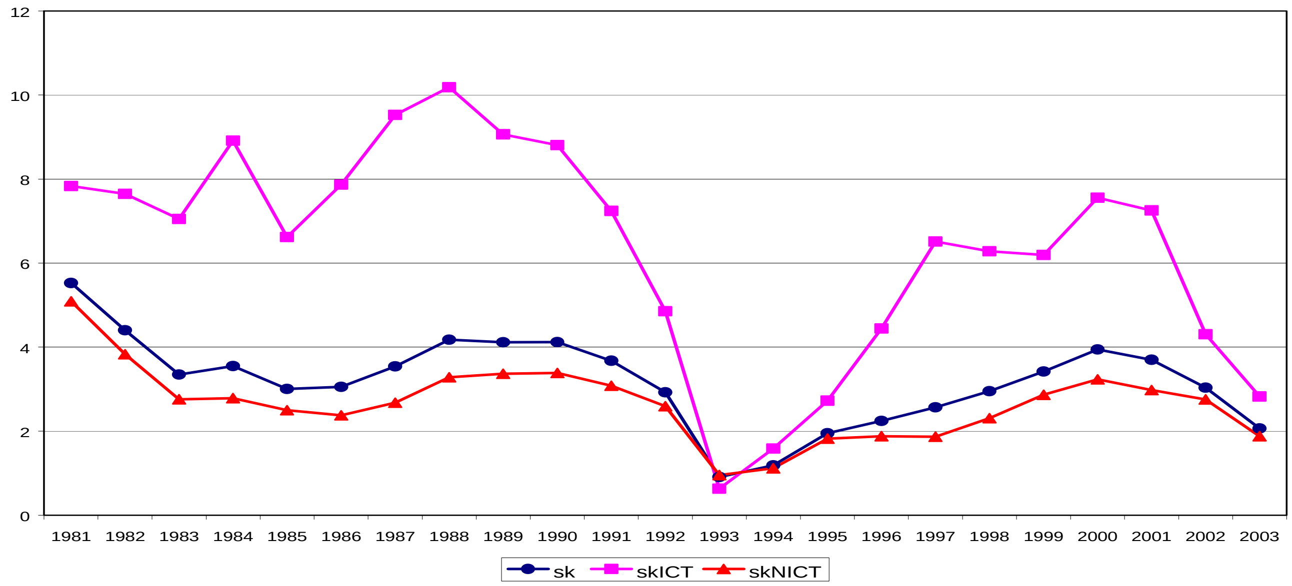


The tested assumptions imply more significant differences if analyzed over shorter time periods. The average growth of alternative measures of capital input differ up to 0.5 percentage point in the 1980-1985 and only of 0.1 percentage points in 1990-2005. However exogenous rate of return always leads to higher growth of the volume of capital services. Chart 1 reports annual logarithmic rates of change of capital services based on exogenous net rate of return. Capital services based on hyperbolic efficiency decay are very similar all over the period, while the measure based on geometric profile is a bit more sensitive to the business cycle. The same results hold adopting endogenous rate of return.

3.2. ICT and Non-ICT capital services

Chart 2 illustrates the annual rates of change in the volume index of total, ICT and Non-ICT capital services. Two results stand out immediately: ICT capital services show the fastest growth and the highest sensitivity to the business cycle.

Chart 2 – Total, ICT and non-ICT Capital Services: 1980-2003



The average service life of ICT capital goods is shorter than that of non-ICTs. Hence ICT productive stock is more influenced by fluctuations of real investment than non-ICT. Further ICT real investment itself is very sensitive to the business cycle (De Arcangelis et al., 2004). The rate of growth of ICT capital services followed two different patterns in the eighties and in the nineties. Since 1981 to 1991, ICT capital services increase ranged from 6% to 10%. In 1992, the currency crisis produced striking negative effects on total capital formation, that induced a considerable decrease in the rate of growth of ICT capital services in 1993-1995 (respectively 0.72%, 1.57% and 2.61%) that recovered "pre-92" rates of growth only in 1997. In 2001-2003, the rate of growth of ICT capital services declined sharply decreasing by 4%.

Table 2 and Chart 3 show the contribution of ICT and non-ICT capital services to the growth of total capital services.

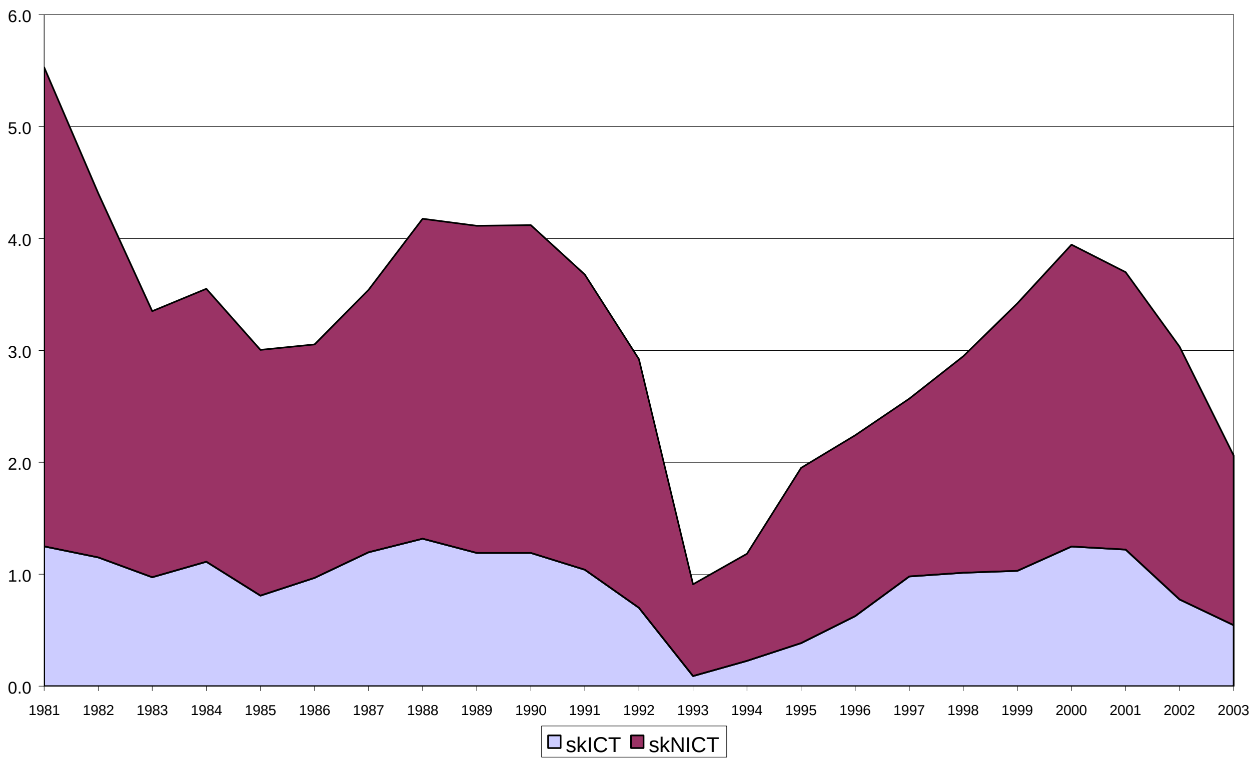
Table 2 – Contributions to Growth of Capital Services (net of residential capital)

Total Economy net of Government Sector

	1980-2003	1980-1985	1985-1990	1990-1995	1995-2000	2000-2003
1. Growth rate of Capital Services [a]	3.2	4.0	3.9	2.2	3.1	3.0
2. Contributions from[b]:						
ICT Capital Services	0.9	1.1	1.2	0.5	1.0	0.9
Non-ICT Capital Services	2.3	3.0	2.7	1.7	2.1	2.1
2. Shares of the contributions from:						
ICT Capital Services	28%	26%	30%	23%	32%	29%
Non-ICT Capital Services	71%	73%	69%	77%	67%	71%
3. Capital income shares:						
ICT Capital	14.8	14.0	12.9	14.2	15.6	18.1
Non-ICT Capital	85.2	86.0	87.1	85.8	84.4	81.9
4. Growth rates of [a]:						
ICT Capital services	6.6	7.9	9.5	3.5	6.4	4.9
Non-ICT Capital services	2.7	3.5	3.1	1.9	2.5	2.6

[a] Average annual rate of growth in the period shown multiplied by 100
[b] Percentage points

Chart 3 - ICT and non-ICT Contributions to the growth of Capital Services: 1980-2003



The most remarkable result is that in terms of the relative contribution of ICT to total capital services growth, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's were even more "ICT oriented". Both in 1985-1990 and in 1995-2000, ICT capital goods accounted for about 30% of the overall growth of capital services, while they accounted for about 20% in 1980-85 and in 1990-95. In the second half of the 80's, ICT capital services recorded the highest absolute contribution (1.2 percentage points), compared to the lowest showed during the first half of the 90's (0.5 percentage points). In 1995-2000 there was a surge in the contribution from ICT, that was only slightly lower than that recorded in the first half of the 80's (1.0 vs. 1.1 percentage points). During the last three years ICT accounted for a smaller share of total capital services (29%).

It should be noticed that the income share of ICT capital grew steadily all over the period (14 percentage points in 1980-1985 and 18.1 percentage points in 2000-2003) and it was considerably higher than the share of ICT over productive capital stock (3.5 percentage points versus 7.5 percentage points all over the period (Tabb. 2 and 3).

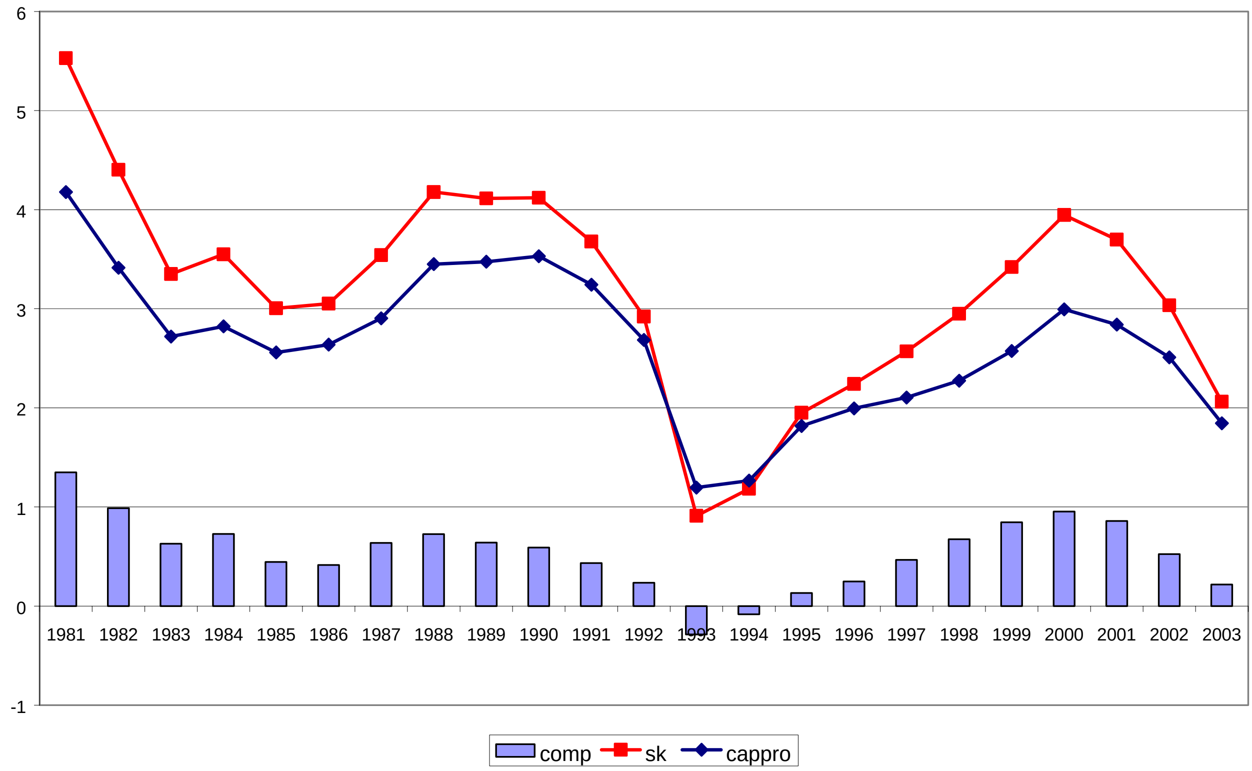
The contributions to the growth of productive capital stock of both kinds of assets are very different? The results reported in Chart 4 and in Table 3 suggest that the answer is yes.

Table 3 – Contributions to Growth of Productive Capital Stock (net of residential capital)
Total Economy net of Government Sector

	1980-2003	1980-1985	1985-1990	1990-1995	1995-2000	2000-2003
1. Growth rate of Productive Stock [a]	2.7	3.2	3.3	2.1	2.4	2.4
2. Contributions from[b]:						
ICT Capital	0.3	0.3	0.5	0.2	0.4	0.4
Non-ICT Capital	2.3	2.9	2.8	1.9	2.0	2.1
2. Shares of the contributions from:						
ICT Capital	13%	9%	14%	10%	17%	15%
Non-ICT Capital	87%	91%	86%	90%	83%	85%
3. Capital stock shares (constant prices):						
ICT Capital	5.4	3.5	4.7	5.8	6.5	7.5
Non-ICT Capital	94.6	96.5	95.3	94.2	93.5	92.5
4. Growth rates of [a]:						
ICT Capital	6.8	8.5	10.0	3.6	6.4	5.0
Non-ICT Capital	2.5	3.0	2.9	2.0	2.1	2.2

[a] Average annual rate of growth in the period shown multiplied by 100
[b] Percentage points

Chart 4 - Capital Services, Productive Stock and Composition Effect: 1980-2003



The first thing to notice is that all over the period, but 1993 and 1994, the volume index of capital services grew faster than aggregate capital stock (i.e. the composition effect is positive[3]) and it seems to be more sensitive to the business cycle (see Bassanetti et al, 2004). As stated above, the reason is that ICT productive capital stock grows relatively faster and it is more sensitive to the cycle than non-ICT capital. Further the weights of ICT capital goods are relatively higher in capital services measure. Because of their shorter service life and higher depreciation rate, they have a relatively higher user-cost (see section 2).

Additionally, ICT contribution to the growth of capital stock is relatively lower than its contribution to the growth of capital services (13% vs. 28% in the whole period 1980-2003) and, when expressed as percentage of capital stock growth, ICT shows the highest contribution in the second half of the 80's. In absolute term, the contribution of ICT capital services was quite the same in the 80's as well as in the 90's.

Table 4 shows the contributions to the growth of capital services in four broad sectors.

[3] The composition effect is positive if there is a substitution effect towards those assets characterized by a relatively higher user cost (marginal productivity).

Table 4 – Contributions to Growth of Capital Services (net of residential capital)

Sectoral results

	Year	Capital Services[a]	Contributions from[b]:			
			ICT		non-ICT	
Manufacturing, Mining, Energy.	**1980-1985**	3.6	0.5	14%	3.1	86%
	1985-1990	3.2	0.5	17%	2.6	83%
	1990-1995	1.8	0.3	17%	1.5	83%
	1995-2000	2.3	0.9	37%	1.5	63%
	2000-2003	1.9	0.6	30%	1.3	70%
	1980-2003	2.6	0.5	21%	2.1	79%
Constructions.	**1980-1985**	3.4	0.4	13%	3.0	87%
	1985-1990	1.1	0.3	31%	0.8	69%
	1990-1995	-1.1	0.0	-3%	-1.1	103%
	1995-2000	3.0	0.5	16%	2.5	84%
	2000-2003	5.7	0.6	10%	5.1	89%
	1980-2003	2.1	0.4	17%	1.8	83%
Trade, Transport, Communications.	**1980-1985**	4.7	1.7	35%	3.0	64%
	1985-1990	5.6	2.4	43%	3.1	56%
	1990-1995	3.6	1.2	32%	2.4	67%
	1995-2000	3.7	0.6	17%	3.1	83%
	2000-2003	3.4	0.3	10%	3.0	90%
	1980-2003	4.3	1.3	31%	2.9	68%
Banking, Finance, Business Services.	**1980-1985**	6.2	3.3	53%	2.8	46%
	1985-1990	5.7	2.8	49%	2.8	49%
	1990-1995	2.4	0.8	33%	1.6	66%
	1995-2000	4.1	3.0	73%	1.1	26%
	2000-2003	4.0	3.1	77%	0.9	23%
	1980-2003	4.5	2.5	56%	1.9	43%

[a] Average annual rate of growth in the period shown multiplied by 100
[b] percentage points

A great deal of heterogeneity emerges both with respect to capital services rates of growth and to the relative contributions from ICT and non-ICT services. In all periods, the growth of total capital services in Manufacturing, Mining and Energy and in Constructions is lower than in the two services sectors, and the best performer is Banking, Finance and Business Services (with the exception of 1990-1995 when the highest growth is in Trade, Transport & Communications). Over the whole period, we find the same results both with respect to absolute and relative contributions of ICT services, even though with some exceptions in some sub-periods. As expected, the most ICT-oriented sector is Banking, Finance & Business Services, where ICT accounted for about 77% of overall capital services in 2000-2003 and about 56% in the entire period.

In terms of contributions to total capital services growth, Manufacturing, Mining and Energy emerges as a non-ICT oriented sector. In 1980-2003, ICT accounted for 0.5 percentage points, a very modest contribution if compared with Trade, Transport & Communications (1.3 percentage points) and with Banking, Finance and Business Services (2.5 percentage points).

However, it should be noticed that the relative lower contribution of ICT to manufacturing could be partly attributed to measurement problems. As a matter of fact, due to the lack of information necessary to obtain a deeper level of disaggregation of machinery and equipment, those capital goods that have a large technological content (semiconductors), but that are not produced by ICT sectors are classified as non-ICT goods. This implies an underestimation of the relative contribution of ICT to the growth of total capital services. Further, it causes a bias in inter sectoral comparisons of the relative contribution of ICT because it is likely that manufacturing would be more affected by the above underestimation problem.

4.CONCLUSIONS

In this paper we show that over 1980-2003, the measure of capital services for the Italian economy is not very sensitive to different assumptions about age-efficiency and age-price profiles and to the choice of the net rate of return. Whereas for shorter horizons the geometric pattern is more sensitive to business cycle fluctuations than the hyperbolic one. Both over the whole period and over shorter horizons, the measures based the on endogenous rate of return records a bit lower average growth rate than the corresponding one based on the exogenous rate. Then we prove that the volume index of capital services grows faster than aggregate capital stock and that it is more sensitive to the business cycle. The analysis of ICT contribution to the growth of capital services showed that it still represents a small fraction of the total productive capital stock (less than 5%) and it accounted for a modest 12% of the growth of productive capital stock in the 1980-2003 period. The small share of ICT in total investment expenditure and total productive capital stock suggest that its contribution to the growth of total capital input is negligible. In this paper we have shown that when capital input is measured in terms of the flow of capital services, this is not the case. In fact, in Italy, in the last twenty-one years, the flow of total capital services grew on average by 3.2% per year and ICT accounted for a remarkable 28% of that total growth.

Another conventional wisdom is that the importance of ICT capital accumulation for capital input growth in Italy in the second half of the 90s has been much higher than in the previous years. Our results in terms of productive capital stock partially confirm this view. In fact, ICT relative contribution to productive capital stock growth shows the highest value in the second half of the 90's. However, the analysis undertaken in terms of capital services gives a different picture. Our findings are that in terms of relative ICT contribution to the growth of total capital services, the 80's were as much "ICT oriented" as the 90's, while in terms of absolute contributions the 80's even were more “ICT oriented”. Both in 1985-1990 and in 1995-2000, ICT capital goods accounted for about 30% of the overall growth of capital services, while they accounted for about 20% in 1980-85 and in 1990-95. The highest absolute contribution from ICT capital services was in the second half of the 80’s (1.2 percentage points), while the lowest was in the first half of the 90’s (0.5 percentage points). Sectoral results show that both the growth of total capital services and ICT contribution were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.

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[i] Not the cost of buying the asset in that period.
[ii] The same argument holds if we define the volume index of the aggregate capital stock as a weighted index of the productive stocks with weights equals to the share of each capital good in the value of the aggregate productive stock at current prices.
[iii] Where the weight is a measure of the share of debt in total liabilities, the cost of debt is the market lending rate and the opportunity cost is the net average rate of return on Italian Treasury bonds (BTP). The sources for these data are Bank of Italy and ISTAT.