NEW TECHNOLOGIES AND THE GROWTH OF CAPITAL SERVICES: 
A SENSITIVITY ANALYSIS FOR THE ITALIAN ECONOMY OVER 1980-2003

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NEW TECHNOLOGIES AND THE GROWTH OF CAPITAL SERVICES:
A SENSITIVITY ANALYSIS FOR THE ITALIAN ECONOMY OVER
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M. IOMMI, C. JONA-LASINIO*

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Abstract

In this paper, we analyse some fundamental questions about the measurement of high-
technology capital and we provide some evidence for the Italian economy over 1980-2003
addressing 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, what is the contribution of technological assets to the growth
of capital services? 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 the relative contribution of ICT 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”; iii) 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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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. The developments of the new economy have raised many essential questions about the measurement of intangible assets and high-technology capital. Indeed the answer to these questions can lead to better assessment of the economy’s long run pace of economic growth and rate of technological advance.

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 the identification of the most appropriate measure of capital services (to be used in productivity analysis) requires a sensitivity analysis to test the responsiveness of capital input to the above different assumptions.

In this paper, we illustrate the methodology adopted by the Italian Institute of Statistics (ISTAT) in calculating 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, what is the contribution of technological assets to the growth of capital services?

Here we provide some evidence for the Italian economy over 1980-2003 at the aggregate and industry level for a detailed asset type classification system. 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 the relative contribution of ICT 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”; iii) both the growth of total capital services and ICT contribution were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.

The structure of the paper is as follows. Section 2 summarizes some issues on the measurement of capital service; section 3 shows the empirical results for the Italian economy in 1980-2003 and some conclusions are drawn in section 4.
2. MEASUREMENT ISSUES

The measurement of the contribution of capital goods to the production process requires a two-stage method (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 the measurement of capital services. The standard model relies on some simplifying assumptions (constant returns to scale, perfect competition and long-run equilibrium and some stringent properties of the production technology necessary to guarantee a consistent aggregation) that are hardly met in real world economies. This implies that the results derived using this framework must be regarded as approximate at best (Hulten, 1990). The following paragraph provides a brief non technical overview of the neoclassical approach to the measurement of capital service (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 estimate of 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 assets.

So that 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 age-efficiency and the retirement functions can be combined together to obtain a set of coefficients $h_i$ to be used to weight past investments at constant prices $I_i$ to calculate the productive capital stock $S_i$ (see Schreyer et al. 2005):

$$S_i = \sum_{t=1}^{T} h_i I_i$$

Since there is scarce empirical evidence both on the efficiency decay of an asset and on its retirement profile, the age-efficiency and the retirement functions are often assumed to follow a specific pattern over the service life (instead of being estimated).

The user cost\(^1\) (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 of financing the purchase of the capital good, its economic depreciation (i.e. the loss in value of a capital good as it ages, that it is described by the sequence of relative prices for different vintages of the asset, referred to as its age-price profile), the capital gains-losses due to asset price changes and the net burden due to the tax structure for business income.

For the purposes of this paper, we refer to a simplified formula of the user cost of capital that does not take into account fiscal factors:

$$u_i = q_i (r_i + d_i - g_i)$$

where $q_i$ is the acquisition price for a new capital good, $r_i$ is the net return on investment, $d_i$ is economic depreciation rate and $g_i$ measures capital gains-losses.

Since direct observations of the user costs exist only for rented capital goods, the usual way to estimate $u_i$ is by imputing directly its components from observable data (as it is usually the case for $r_i$ and $g_i$ and as it might be the case for $d_i$, provided there is empirical evidence on new and second-hand asset prices) or by assuming that they follow a specific pattern (as it is usually the case for $d_i$ when there are no observations of second-hand asset prices).

A crucial result that emerges from the neoclassical approach is that the price of an asset depends on the quantity of services it is able to provide, and thus the assumptions on age-efficiency and depreciation profiles cannot be made independently of each other.

More precisely, the basic idea is that the price of an asset depends on the discounted flow of income it will generate during its remaining lifetime and the flow of income depends on both quantity and price of services. In other words, economic depreciation and efficiency decay follow two (in general) different but not independent patterns over time.\(^2\)

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\(^1\) Jorgenson and Griliches (1967) linked the measurement of both the user cost and capital services.

\(^2\) Since the price of an asset at a given year depends on the flow of services 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).
Full consistency between the estimates of productive capital stock and user cost can be obtained assuming a specific profile for the age-efficiency function and then deriving the age-price profile by means of the relationship that expresses the price of an asset as a function of the discounted flow of its future income. 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 net capital stock and consumption of fixed capital.

2.2. Aggregation Across Assets

Once the productive stock for different types of assets have been estimated, they have to be aggregated to get a measure of the overall flow of capital services provided by the stocks (i.e. a volume index of capital services).

The aggregation procedure requires the choice of both a specific aggregation formula and of a system of weights.

In the standard approach, the aggregation is implemented by means of 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.

Let \( S_i^t \) be the productive stock of type \( i \) asset, \( u_i^t \) is its user-cost and \( S \) is the flow of total capital services. By means of the Tornqvist aggregation, the (logarithmic) rate of change of \( S \) is:

\[
\begin{align*}
\ln\left(\frac{S_t}{S_{t-1}}\right) = & \sum_{i=1}^{n} 0.5 \left( v_{i,t}^{\prime} v_{i,t} \right) \ln\left(\frac{S_i^t}{S_{i,t-1}}\right)
\end{align*}
\]

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.

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.
Changing weight indexes 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).

Cost-share weights allow to account for the heterogeneity of marginal products 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 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 an 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 fail to account for changes in the composition of capital stock. One dollar worth of investment in computers increases aggregate capital stock as much as one dollar worth of investment in structures: the growth of aggregate capital stock is not affected by changes in its composition.\(^3\)

The difference between the growth rates of the cost-shares weighted 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 towards assets that provide a relatively higher flow of services per unit of capital.

### 2.3 ICT and Non-ICT Capital Services

The standard growth accounting model outlined in the previous paragraph is modified by a breakdown of the flow of capital services into ICT and non-ICT services to evaluate the impact of technological assets on the growth of aggregate 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 \(n_i\) ICT-type assets and \(n_n\) Non-ICT (with \(n_i + n_n = n\)), then the indexes of ICT and Non-ICT capital services (respectively \(\ln(S_{i_t}/S_{i_{t-1}})\) and \(\ln(S_{n_t}/S_{n_{t-1}})\)) are:

\(^3\) 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 (Hill, 1999).
\[ \ln \left( \frac{S_t}{S_{t-1}} \right) = \sum_{i=1}^{n} 0.5 \left[ v_i + v_i' \right] \ln \left( \frac{S_i}{S_{i-1}} \right) \]  \hspace{1cm} (7) 

where \( v_i = u_i S_i' / \sum_{i=1}^{n} u_i S_i' \) and 

\[ \ln \left( \frac{SN_t}{SN_{t-1}} \right) = \sum_{i=1}^{n} 0.5 \left[ vn_i + vn_i' \right] \ln \left( \frac{S_i}{S_{i-1}} \right) \]  \hspace{1cm} (8) 

where \( vn_i = u_i S_i' / \sum_{i=1}^{n} u_i S_i' \).

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 (for an application to the Italian economy see Bassanetti et al., 2004).

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

The contribution of ICT (Non-ICT) capital services to aggregate 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:

\[ \ln \left( \frac{S_t}{S_{t-1}} \right) = 0.5 \left[ ci_i + cn_i \right] \ln \left( \frac{SI_t}{SI_{t-1}} \right) + 0.5 \left[ cn_i + cn_i' \right] \ln \left( \frac{SN_t}{SN_{t-1}} \right) \]  \hspace{1cm} (9) 

where \( ci_i = \sum_{i=1}^{n} u_i S_i' / \sum_{i=1}^{n} u_i S_i \) and \( cn_i = \sum_{i=1}^{n} u_i S_i' / \sum_{i=1}^{n} u_i S_i' \).

i.e. \( ci_i \) is the share of ICT capital goods in the value of total cost for capital services in period \( t \) and \( cn_i \) 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 capital gains term.

The estimates of capital input used in the productivity measure published by ISTAT relies on the following assumptions. The productive capital stock of each type of asset 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\(^4\) (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.

In this paper we evaluate the impact on the growth of capital input of different assumptions on depreciation rates, rates of return, and age-efficiency profiles.

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.

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\(^4\) 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.
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.

3.1. Sensitivity analysis

In this section we present a comparison between alternative measures of capital input obtained testing 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 \(^2\) (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 above mentioned eight measures of capital services and the corresponding measures of aggregate productive capital stock.

\(^2\) The rate of depreciation for the geometric patterns, \(\delta\), as been calculated as \(\delta = \frac{R}{T}\), where \(R\) is the so-called declining-balance rate and \(T\) is the average service life. For each asset, \(T\) is the same one used in the other models. The value of \(R\) is based on Hulten and Wycoff (1981) and is set equal to 0.95 for non-residential buildings and to 1.65 for all other assets.
Table 1 - Growth of Capital Services (net of residential capital).

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<tbody>
<tr>
<td>hlbi</td>
<td>3.2</td>
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<td>3.9</td>
<td>2.2</td>
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<td>hlen</td>
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<tr>
<td>hibi</td>
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<td>4.1</td>
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<td>hien</td>
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<td>3.9</td>
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<td>ggbi</td>
<td>3.3</td>
<td>3.9</td>
<td>4.1</td>
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<td>ggen</td>
<td>3.1</td>
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<tr>
<td>llbi</td>
<td>3.0</td>
<td>3.6</td>
<td>3.7</td>
<td>1.8</td>
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<tr>
<td>llen</td>
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<td>capproh</td>
<td>2.7</td>
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<td>capprol</td>
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Average annual rate of growth in the period shown multiplied by 100

Over the whole period we find that only minor differences (if any) exist between the consistent or broadly consistent measures of capital services (from hlbi to ggen). The growth of capital input is comprised in a range between 3.1% and 3.3%. The three measures (hlen, hien, ggen) based on endogenous rate of return record a bit lower average growth than the corresponding one based on the exogenous rate of return (hlbi, hibi, ggbi). On the other hand, the non consistent measure (llbi, llen) (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).
The tested assumptions entail 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 0.1 percentage points in 1990-2005. But the 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 the geometric profile is a bit more sensitive to the business cycle. The same results hold adopting the 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 compared to Non-ICT.
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 relatively more 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, the increase of technological capital ranged from 6% to 10%. In 1992, the currency crisis produced striking negative effects on total capital formation, inducing a considerable decline of 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, 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)

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<td>4.0</td>
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<td>2. Contributions from <em>b</em>:</td>
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<td>ICT Capital Services</td>
<td>0.9</td>
<td>1.1</td>
<td>1.2</td>
<td>0.5</td>
<td>1.0</td>
<td>0.9</td>
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<td>3.0</td>
<td>2.7</td>
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<td>2. Shares of the contributions from:</td>
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<tr>
<td>ICT Capital Services</td>
<td>28%</td>
<td>26%</td>
<td>30%</td>
<td>23%</td>
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<tr>
<td>Non-ICT Capital Services</td>
<td>71%</td>
<td>73%</td>
<td>69%</td>
<td>77%</td>
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<td>71%</td>
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<td>3. Capital income shares:</td>
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<td>ICT Capital</td>
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<td>14.2</td>
<td>15.6</td>
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<td>86.0</td>
<td>87.1</td>
<td>85.8</td>
<td>84.4</td>
<td>81.9</td>
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<td>4. Growth rates of <em>a</em>:</td>
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<tr>
<td>ICT Capital services</td>
<td>6.6</td>
<td>7.9</td>
<td>9.5</td>
<td>3.5</td>
<td>6.4</td>
<td>4.9</td>
</tr>
<tr>
<td>Non-ICT Capital services</td>
<td>2.7</td>
<td>3.5</td>
<td>3.1</td>
<td>1.9</td>
<td>2.5</td>
<td>2.6</td>
</tr>
</tbody>
</table>

*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 technological assets 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”. 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 results reported in Chart 4 and in Table 3 suggest that the contributions to the growth of productive capital stock of both types of assets are quite different.

Table 3 – Contributions to Growth of Productive Capital Stock (net of residential capital)

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

a Average annual rate of growth in the period shown multiplied by 100
b Percentage points
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\(^6\)) 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, the contribution of ICT 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 a 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.

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\(^6\) The composition effect is positive if there is a substitution effect towards those assets characterized by a relatively higher user cost (marginal productivity).
A great deal of heterogeneity emerges both with respect to the rates of growth of capital services and to the relative contributions of ICT and non-ICT services. The rate of growth of total capital services in Manufacturing, Mining and Energy and in Constructions is always lower than in the two service 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 the absolute and the 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 the contributions to the growth of total capital services, 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. Actually, 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 intersectoral 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. Over the whole period as well as over shorter horizons, the measures based on endogenous rate of return records a bit lower average rate of growth than the corresponding based on the exogenous rate. Then we prove that the volume index of capital services grows faster than the 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. But 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, the relative contribution of ICT to the growth of productive capital stock 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 the relative contribution of ICT 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”. 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 of 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 the growth of total capital services as well as the contribution of ICT were higher in the service sectors than in Manufacturing, Mining and Energy and Constructions.
REFERENCES