EU KLEMS

Capital Services and Total Factor Productivity Measurements: Impact of Various Methodologies for Belgium

Working paper nr. 13

Bernadette Biatour, Geert Bryon and Chantal Kegels

EU KLEMS WORKING
PAPER SERIES

Capital Services and Total Factor Productivity Measurements: Impact of Various Methodologies for Belgium

Working paper nr. 13

Bernadette Biatour, Geert Bryon and Chantal Kegels

EU KLEMS Project
Productivity in the European Union: A Comparative Industry Approach

March 2007

This project is funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, "Policy Support and Anticipating Scientific and Technological Needs".

Capital Services and Total Factor Productivity Measurements: Impact of Various Methodologies for Belgium

Bernadette Biatour, bbi@plan.be,
Geert Bryon, gb@plan.be,
Chantal Kegels, ck@plan.be[1]

Federaal Planbureau

March 2007

Abstract

This Working Paper presents the different methodologies currently used to construct a volume index of capital services and analyzes the effects of methodological changes on capital services and total factor productivity estimates for Belgium over the period 1970-2004. The measurement of capital services is realized in two steps. First, productive capital stocks have to be estimated for each type of asset. Two methodologies are generally used: the geometric and the hyperbolic profile. Secondly, these stocks are aggregated, using the user costs of capital (ex-ante or ex-post approach) as weights to derive an overall index. For the economy as a whole and the entire period, under an ex-post approach, the volume indices of capital services estimated with a hyperbolic age-efficiency profile grow at a higher rate than the indices estimated with a geometric profile. This general conclusion is, however, not observed in every sector. Under an ex-ante approach, the different volume indices are quite similar for the whole economy, even if the indices grow generally at a slightly higher rate in the case of a geometric pattern. A higher growth rate of the volume indices generates a higher capital contribution and, consequently, a lower tfp contribution. Over long periods of time, the different tfp estimates are relatively similar. Over shorter periods, the different methodologies generate more significant variations in the tfp contribution.

Jel Classification – C81, D24, O40.

Keywords - Productive capital stocks, User costs, Capital services, TFP.

---

[1] Acknowledgements: The authors are grateful to Chantal Vandevoorde from the translation team for her careful reading. The data analysed are coming from the Belgian part of the euklems project funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, ”Policy Support and Anticipating Scientific and Technological Needs”.

Executive Summary

This working paper presents the different methodologies currently used to construct a volume index of capital services and analyzes the effects of methodological changes on capital services and total factor productivity estimates for Belgium over the period 1970-2004. This working paper is realized within the framework of the European EUKLEMS project, in which the Federal Planning Bureau participates.

TFP measurements are essential to study economic growth determinants. They depend on the availability and quality of data concerning the other sources of growth: the contribution of capital and labour. According to the OECD recommendations, the appropriate measurement of capital input for productivity studies is the flow of services produced by capital assets, rather than capital stocks. In Belgium, as in other many countries, no official data exit on capital services.

The measurement of the capital services is realized in two steps. First, productive capital stocks have to be estimated for each type of investment goods called assets. Then, these stocks are aggregated with the user costs of capital as weights to derive a global index measuring the productive contribution of all types of capital assets to output growth. Two methodologies are generally used to construct productive capital stocks: the geometric profile and the hyperbolic profile. For each profile, several assumptions have to be made such as the choice of the functional form of the retirement function or of the maximum service life. For the computation of the user costs, we have the choice between an ex-ante and an ex-post rate of return of capital.

After a theoretical presentation of the different methodologies currently used to construct a volume index of capital services, the results show that for the whole economy and for the majority of capital assets, the estimation of productive capital stocks is higher in level and growth rate, when it is computed with a hyperbolic age-efficiency profile than when a geometric profile is assumed. The different methodological options within each age-efficiency profile also have consequences on productive capital stocks.

Concerning the user costs of capital, the evolution of the estimation seems to be more influenced by the choice between an ex-post and an ex-ante rate of return than by the assumed depreciation profile (geometric or hyperbolic).

For the economy as a whole and the entire period 1970-2004, under an ex-post approach, the volume indices of capital services estimated with a hyperbolic age-efficiency profile grow at a higher rate than the indices estimated with a geometric profile. This general conclusion is, however, not observed in every sector. Under an ex-ante approach, the different volume indices are quite similar for the whole economy, even if the indices grow generally at a slightly higher rate in the case of a geometric pattern. In the case of a hyperbolic profile, a longer maximum service life and/or a higher β parameter (slower loss of efficiency) increase the volume index of capital services in level and in growth rate. A higher growth rate of the volume indices generates a higher capital contribution to output growth and, consequently, a lower tfp contribution. Concerning the retirement function, the growth rates of indices are slightly higher with a delayed-linear function, than with a lognormal and are the lowest with a linear function. In the case of a geometric profile, the choice between the two tested depreciation rates has no influence on the volume index of capital services for the total economy. However, differences appear in the volume indices of industries.

Over long periods of time, the different tfp estimates are relatively similar. Over shorter periods, the different methodologies generate more significant variations in the TFP contribution. Over the recent period 2000-2004, the average annual TFP contribution to output growth for the whole economy is estimated between 0.04% and 0.27%, according to the made assumptions. It also appears that, for the whole economy, the variations in TFP contribution are larger when an ex-post user cost is used.

In summary, this sensitivity analysis shows that methodological choices have certain consequences on the volume index of capital services and consequently on the estimation of the TFP contribution to growth. These consequences are more important when the analysis is realized at the industry level and when the studied period is short, underlying the importance of long-term perspective to analyze productivity evolution. It seems credible that the appropriate age-efficiency profile differs according to the kind of assets and the industry in which these assets are used. Empirical studies on age-efficiency and retirement profiles of assets are necessary to determine the best appropriated profiles.

Table of Contents

1. Introduction

One of the main sources of economic growth is the increase in the total productivity of inputs used in the production process, which reflects greater overall efficiency in the utilisation of inputs due to innovation. Therefore, measuring total factor productivity (TFP) is essential to study economic growth determinants. TFP measurements depend on the availability and quality of data concerning the other sources of growth: the contribution of capital and labour. TFP growth is indeed estimated as a residual in the decomposition of economic growth and includes, therefore, measurement errors in the absence of perfect statistical measurements of capital and labour, especially in terms of quality improvements. In many productivity studies, the contribution of capital is measured by using stocks of assets. However, according to the OECD Manuals "Measuring productivity" and "Measuring capital", the appropriate measurement of capital input is the flow of services produced by capital assets, rather than capital stocks for the following reasons:

- The other variables in the growth accounting model are all flows. The use of net or gross stocks is therefore not consistent.
- Gross or net stocks do not reflect the productive efficiency of capital assets declining with the age. The gross capital stock values all assets in use as if they were still new and the net capital stock measures the market value of capital assets. The reduction in the value of fixed assets (depreciation/consumption of fixed capital) is not necessarily identical to the loss of productive efficiency.
- In calculating capital stocks, each asset in the stocks is weighted by its market value, independently of its service life.

Consequently, to have a good measurement of the TFP residual, it is important to evaluate flows of capital services, even if no official data exist, as it is the case in Belgium. The measurement of capital services is realized in two steps. The first step consists in the calculation of productive capital stocks, which are equivalent to the quantity of services produced by each type of asset. The second step is the construction of an aggregate measurement of the productive contribution of the different types of capital assets (the volume index of capital services). The weights used to derive an overall index are the user costs of capital or rental prices, which correspond to the price of the services.

To compute the productive capital stocks and the user costs of capital, alternative methodologies exist. The productive capital stock can be estimated, for example, by using a geometric or hyperbolic age-efficiency function. These functions can be combined with a normal, a linear or a simultaneous exit retirement function. For the computation of the user costs, we have the choice between an ex-ante and an ex-post rate of return.

The objective of this paper is to present the different methodologies currently used to construct a volume index of capital services and to test how sensitive the measurement of capital services is to methodological changes. We also evaluate the impact of the different capital services estimates on the measurement of the total factor productivity. We provide results for Belgium for the period 1970-2004. This paper is realized within the framework of the European EUKLEMS project, in which the Federal Planning Bureau participates. This project aims to analyze the evolution of productivity at a detailed industry level by creating a database on measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level for all European Union member states from 1970 onwards. In this database, capital services are measured according to a common methodology that is compared to the other methodologies developed in this paper.

The structure of the paper is as follows. Chapter 2 places the analysis in the growth accounting framework, chapter 3 presents the main methodologies to estimate capital services, chapter 4 shows the results for Belgium and chapter 5 contains a conclusion.

2. The growth accounting framework

Capital and labour services measurements allow to assess the contributions of capital and labour inputs to economic growth and to estimate the contribution of total factor productivity (TFP), by using the general growth accounting framework. This model, pioneered by Solow (1957), starts with a neoclassical production function[2],

$$Y = Af(K,L)$$

where Y is the GDP level, A the technology level, K the capital input that includes the different types of capital inputs (K_1, K_2,…, K_n), L the labour input.

$$\Delta Y = \Delta A f(K,L) + A\frac{\Delta f(K,L)}{\Delta K}\Delta K + A\frac{\Delta f(K,L)}{\Delta L}\Delta L$$
$$g = \frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \frac{F_K K}{f(K,L)}\frac{\Delta K}{K} + \frac{F_L L}{f(K,L)}\frac{\Delta L}{L}$$

Under the assumptions of competitive product and factor markets and constant returns to scale, the production factors are remunerated at their marginal productivity, which means:

$$w = AF_L$$
$$r = AF_K$$

We can then rewrite the growth rate of the economy as:

$$g = \frac{\Delta A}{A} + \alpha\frac{\Delta K}{K} + (1-\alpha)\frac{\Delta L}{L}$$

where α is the share of capital in the GDP and $(1-\alpha)$ the share of labour in the GDP.

The part of GDP growth that is not explained by the capital and labour rates of growth is assumed to be the TFP growth and is called the Solow residual. Different estimates of capital growth rates therefore have an impact on the TFP residual.

---

[2] In this production function, the augmentation of A is “Hicks-neutral”. The technical progress allows to produce more with a same proportion of decrease in inputs use.

3. Capital services estimates

3.1 The productive capital stock

To quantify the contribution of capital to the production process, it is recommended to estimate the flow of services delivered by each type of asset, during a period of time. These flows of services called capital services, correspond to a quantity concept and not to a price or value concept of capital. For example, the service flows generated by a truck are tonne-kilometres, or cubic metres of storage space for a warehouse (OECD (2001a)). The price of capital services is the user cost of capital or the rental price. Due to wear and tear that reduce the asset efficiency, the quantity of services produced by an asset declines during its service life (total period during which the asset remains in use in the productive process). These flows of services produced by an asset during the accounting period are usually not observable and have to be measured by a proxy (Iommi, Jona-Lasinio (2005)). Capital services are traditionally approximated by assuming that the service flows from an asset are a constant proportion of the productive capital stock of the asset.

For an asset with a service life of T years, the productive capital stock is defined as a sum of the past investment weighted by the age-efficiency profile which captures the loss of productive efficiency of the asset as it ages. Instead of using the concept of "productive capital stock", the OECD Manual "Measuring Capital" says that the assets of a particular type are converted into standard efficiency units, because productive capital stock is a very different concept with regards to the usual net or gross stock. There is very little empirical evidence on the way in which assets lose their efficiency with age (OECD (2001a)). Two age-efficiency profiles are traditionally used to describe the evolution of the productive efficiency of the asset with its age: the geometric profile and the hyperbolic profile.

The measurement of productive capital stock of the different kinds of assets is the first step to estimate the volume index of capital services, i.e. an aggregate measurement of the productive contribution of the different kinds of assets.

3.1.1 Geometric age-efficiency profile

The geometric age-efficiency profile assumes that the productive efficiency of an asset falls at a constant rate each year. It means that efficiency declines by the largest amount in the first years of service and then by decreasing amounts each subsequent year. The geometric profile is empirically frequently used, because of its simplicity. The geometric profile is used by Statistics Canada, by many researchers like Jorgenson (for example: Jorgenson and Stiroh (2000)), Fraumeni (1997), O'Mahony (2002), Hulten and Wyckoff (1996)[3], Oulton (2001). The European EUKLEMS project also applies a geometric pattern to estimate productive capital stocks for all countries.

---

[3] Cited in Oulton (2001).

The productive capital stock (S) for an asset i at time t is given by:

$$S_t^i = \sum_{\tau=0}^{\infty} (1-\delta^i)^{\tau} I_{t-\tau}^i \qquad \text{Schreyer (2003)}$$

with $I_{t-\tau}^i$ investment at constant price in asset of type i at time t-τ and δ^i the geometric depreciation rate of the asset of type i.

It is then assumed that the flow of capital services K is proportional to the productive stock S:

$$K_t^i = \lambda^i S_t^i$$

The proportionality factor λ measures the utilisation of capacity of the capital stock which varies with the business cycle. For simplicity, this factor is frequently set to unity for all types of assets[4]. The volume index of capital services estimated in this case measures then the potential flow of capital services that could be provided by the capital stock and not the flow of services that were actually produced (OECD (2001a)). These fluctuations of the rate of utilisation of the capital stock that are not taken into account are picked up by the residual TFP.

In the geometric age-efficiency function, maximum service life is assumed to go towards infinity. By simplification, we have limited in our calculations the infinity to 2 times the service life of the asset. In the case of the geometric profile, no retirement function is explicitly formulated (Schreyer, Diewert and Harrison (2005)). It is assumed that the geometric decline captures both the effects of wear and tear and retirement (Schreyer (2003)). So, no specific retirement function describing the share of assets still in service during the service life is necessary in the formula.

The depreciation rate (δ) depends on the declining balance rate (R) and the service life of each asset n (δ=R/n). To estimate the depreciation rate, we use, like many authors, the BEA declining-balance rates given by Fraumeni (1997) and the service life of the assets given by the Belgian national accounts. Some authors use the double declining balance method (R=2). Other authors use directly the depreciation rate given by Fraumeni (1997). Finally, for ICT assets, depreciation rates are often set at the common rates used by Jorgenson and Stiroh (2000) and Oulton (2001): 0.315 for computing equipment, 0.315 for software and 0.115 for communications equipment.

3.1.2 Hyperbolic age-efficiency profile

With a hyperbolic age-efficiency profile, the efficiency declines slowly in the first period and at an increasing rate towards the end of the asset's life.

---

[4] See Schreyer et al.(2003) for another assumption, cited in Schreyer (2003).

For each of the homogenous asset types, the productive stock at time t is constructed as follows[5]:

$$K_t^i = \sum_{\tau=0}^{T} h_\tau^i . F_\tau^i . I_{t-\tau}^i$$

In this expression, $I_{t-\tau}^i$ is the real investment expenditure on asset type i at time t-τ. The factor h_τ^i is the efficiency profile. This function is declining and takes values between unity (when an asset is new) and zero (when the asset has lost its total productive capacity). F_τ^i is the retirement function that indicates the share of assets of age τ that are still in service at time t. F_τ^i is also declining and takes values between unity (when all assets are in service) and zero (when all assets of a particular vintage have been retired) (OECD (2001a)). T is the maximum service live. Indeed, it is unlikely that all assets of a particular type disappear exactly at the average service life. After the maximum service life, all capital goods are retired. In Schreyer (2003), the maximum service life is equal to 1.5 times the average service life (n). The Institute of National Accounts (2002:19) assumes that T=2n for its calculation of the stock of non-ICT assets. Several other relations between average and maximum service life are found in the literature. For instance, van der Wiel (2001) and Vijselaar and Albers (2002) take T=n in the above formula, Meinem et al. (1998) assume that $T = n\beta^2 /[\beta + (1-\beta) \log(1-\beta)]$ and Mohr and Gilbert (1996) take the expected value of the hyperbolic function for all possible service lives between 0.5n and 1.5n.[6] According to Pamukçu and Van Zandweghe (2002), the results are sensitive to the choice of T.

The hyperbolic age-efficiency profile is used by the Australian Bureau of Statistics and the US Bureau of Labor Statistics, and by other researchers such as Wolfl and Hajkova (2006), Mas, Pérez and Uriel (2006), and Schreyer and Dupont (2006). According to the OECD (2001b), this profile is also a plausible pattern to many kinds of assets.

a. The hyperbolic efficiency function

The hyperbolic efficiency profile of a τ-year old asset i is calculated by the following function:

$$h_\tau^i = \frac{(T-\tau)}{(T-\beta\tau)} \qquad \text{(Schreyer (2003))}$$

with T the maximum service life and β the slope coefficient. Pamukçu and Van Zandweghe (2002) have observed that variations in the value of β have a negligible impact on the results. Schreyer (2003) sets the parameter at 0.8. The US Bureau of Labour Statistics and the Australian

---

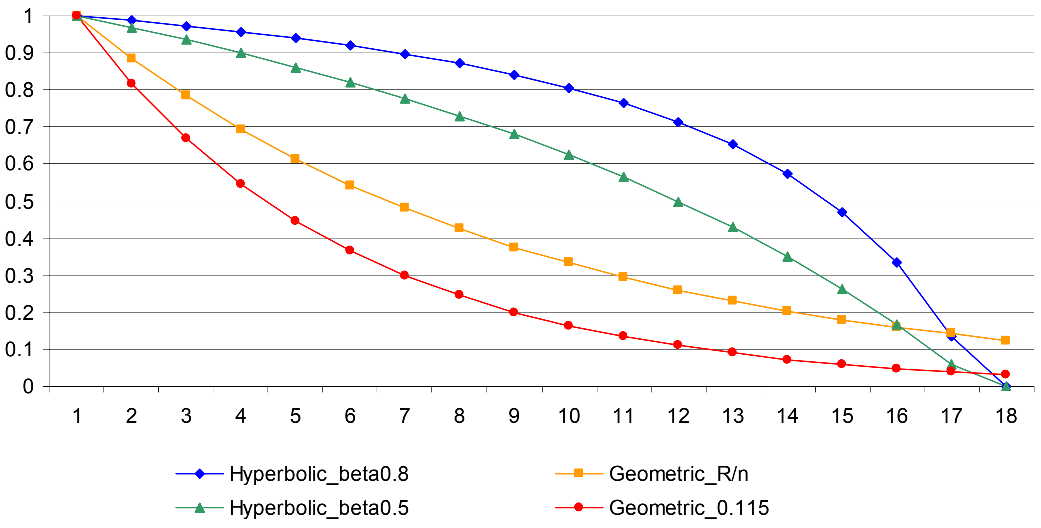
[5] It is assumed that the flow of capital services is equal to the productive capital stock.

[6] Cited in Pamukçu and Van Zandweghe (2002).

Bureau of Statistics set the parameter at 0.5 for machinery and equipment and at 0.75 for buildings and structures. A higher value of β implies that the asset loses its efficiency more slowly than in the case of a smaller value. With β set at 1, the hyperbolic function gives a constant or "one-hoss shay" age-efficiency profile that will be explained in the next section. With β set at 0, the function h is equivalent to a linear function. The Australian Bureau of Statistics uses this value of β for mineral exploration because it believes that there is no efficiency decline in the knowledge acquired through exploring for minerals (OECD (2001a)).

Figure 1 shows the difference between two hyperbolic and two geometric age-efficiency profiles for an asset with an average service life of 11 years (communications equipment). For the hyperbolic profiles, the parameter β is fixed at 0.8 in the first case and at 0.5 in the second case. The maximum service life is equal to 1.5 times the average service life. For the geometric profiles, the depreciation rate is calculated with a declining balance rate set at 2 in the first case and is fixed to the usual rate (0.115) given by Jorgenson and Stiroh (2000) in the second case. Figure 1 shows that the hyperbolic pattern generates a slower loss in productive efficiency than the geometric pattern over the first years of the asset's service life and a faster fall at the end of the service life. In no case, the asset is scrapped after 11 years.

Figure 1: Hyperbolic and geometric age-efficiency patterns – Average service life 11 years



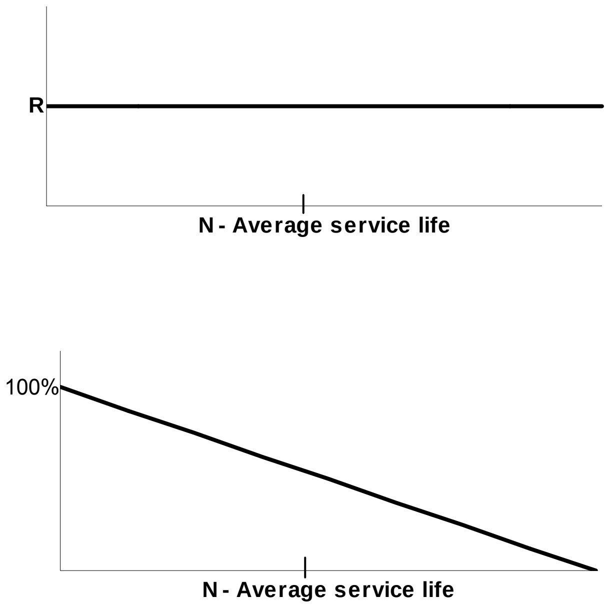
b. The retirement function

Four types of retirement functions are traditionally used: simultaneous exit, linear, delayed linear and bell-shaped. The probability density functions given below indicate the rate of retirement (R) over the lifetimes of the longest-lived member of a group of assets of a particular type (= mortality functions) and the cumulative functions (= the survival functions) represent the proportion of the members of a group of assets that are still in service at each point during the lifetime of the longest-lived member of the group (OECD (2001a)). F_{τ}^{i} is declining with time and takes values between unity (when all assets are in service) and zero (when all assets of a particular vintage have been retired).

The linear function

The linear function assumes that the assets are discarded at the same rate each year.

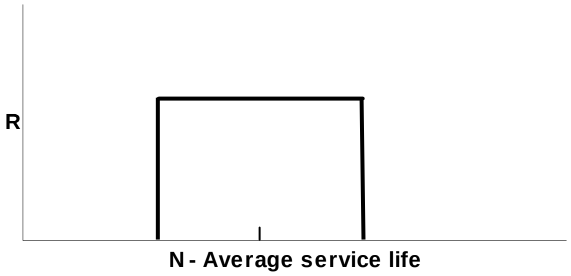
Figure 2: The linear retirement function

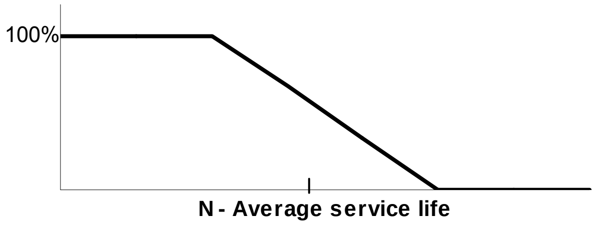


The delayed linear function

With the linear pattern, the retirements start immediately after the assets are installed and this is generally considered as an unrealistic assumption. With a delayed linear retirement pattern, retirements start later and finish sooner.

Figure 3: The delayed linear function

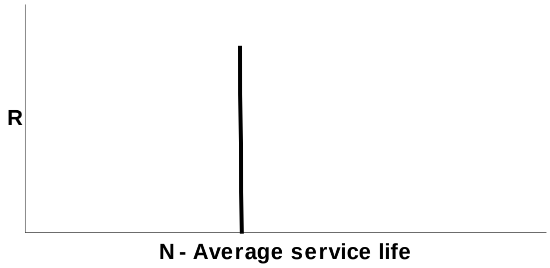


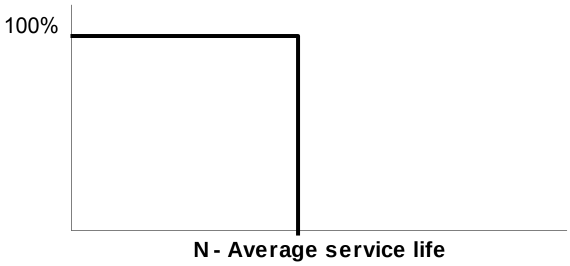


The simultaneous exit

The simultaneous exit mortality function assumes that all assets are retired from the capital stock at the moment when they reach their average service life.

Figure 4: The simultaneous exit

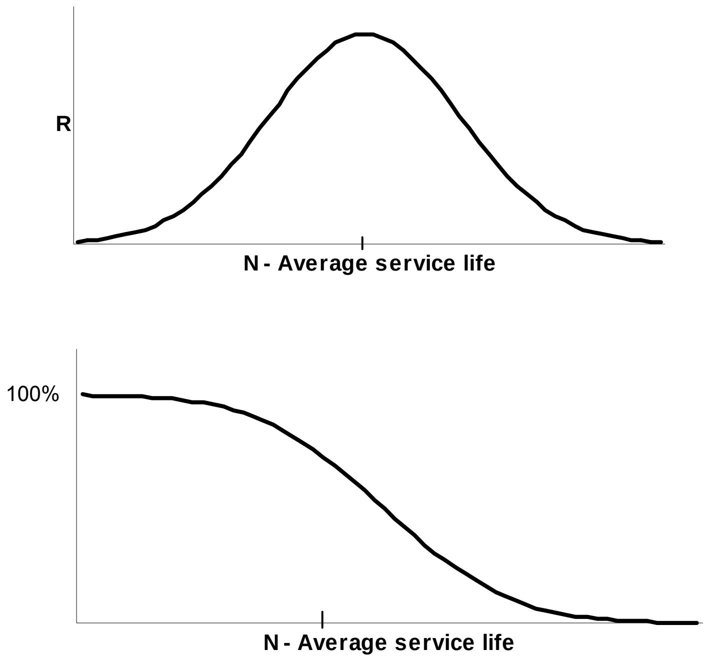




The bell-shaped function

With a bell-shaped mortality pattern, retirements start gradually after the installation of the assets, reach a peak around the average service life and then slow down in later years. Several mathematical functions are available to produce bell-shaped retirement patterns: gamma, quadratic, Weibull, Winfrey, normal and lognormal functions. The last two are the most widely used functions and are also these that we have tested.

Figure 5: The bell-shaped function



According to the OECD Manual “Measuring Capital”, simultaneous exit and linear decline are clearly unrealistic. Among the other two discard patterns – delayed linear and bell-shaped – it is the bell-shaped distributions that are the most plausible.

3.1.3 Other age-efficiency profiles

There exist two other age-efficiency profiles, more rarely used in the empirical analyses: the constant and the linear profile.

The constant age-efficiency profile or the “one-hoss shay” pattern corresponds to a situation where the assets do not lose efficiency and produce consequently the same quantity of services during their service life. According to the OECD (2001a), there are probably rather few assets that maintain constant efficiency throughout their working lives. The constant profile is a particular case of the hyperbolic profile, with the parameter β set at 1.

With the linear profile, the efficiency falls by a constant amount each year, which means that the efficiency falls at a faster rate as the asset ages. This profile can be seen as a compromise between the geometric and the hyperbolic profile.

3.2 The volume index of capital services

Because many different kinds of assets intervene in the production process, an aggregate measurement of capital services has to be calculated. Jorgenson (1963) and Jorgenson and Griliches (1967) were the first to develop aggregate capital services measurements that take the heterogeneity of assets into account. They defined the flow of quantities of capital services individually for each type of asset, and then applied asset-specific user costs as weights to aggregate across services from the different types of assets.

3.2.1 The user cost

The price of capital services is given by the user cost of capital or the rental price of services. These costs reflect the amount that would be billed on a functioning market for the renting of an asset for one period. However, there are often no complete markets for capital services because many capital goods are owned and rental prices have to be estimated. The implicit rent that capital goods owners "pay" themselves gives rise to the terminology "user costs of capital" (Schreyer (2003)).

The product of the price of capital services (user cost of capital) and the quantity of services (the productive capital stock) gives the value of capital services.

The computation of the user cost/rental price is derived from the assumption that in a well-functioning asset market, the purchase price of a capital good equals the discounted value of the rentals/value of services that the asset is expected to generate in the future. This equilibrium condition corresponds to the equation (Schreyer (2003)):

$$q_{t,o}^{i} = \sum_{\tau=0}^{\infty} uc_{t+\tau+1,\tau}^{i} (1+r)^{-(\tau+1)} \tag{1}$$

With, $q_{t,o}^{i}$ the purchase price in year t of a new (zero year old) asset of type i and $uc_{t+\tau+1,\tau}^{i}$ the rental price that this asset is expected to fetch τ periods later (t+τ), when the age of the asset will be τ. The formulation of equation (1) implies that the rentals are received at the end of each period and that the asset is acquired at the beginning.

Then the price for a one year old asset in the period t+1 is equal to:

$$q_{t+1,1}^{i} = \sum_{\tau=0}^{\infty} uc_{t+\tau+2,\tau+1}^{i} (1+r)^{-(\tau+1)} \tag{2}$$

By subtracting (2) from (1) multiplied by (1+r), we obtain:

$uc_{t+1,0}^{i} = q_{t,o}^{i}(1+r) - q_{t+1,1}^{i}$, which is equivalent to $uc_{t+1,0}^{i} = q_{t,o}^{i}\left(1+r-\frac{q_{t+1,1}^{i}}{q_{t+1,0}^{i}}\frac{q_{t+1,0}^{i}}{q_{t,o}^{i}}\right)$

Finally, this expression can be transformed into $uc^i_{t+1,0} = q^i_{t,0}(r + \delta^i_{t+1} - \zeta^i_{t+1} + \delta^i_t \zeta^i_{t+1})$

or $uc^i_{t,0} = q^i_{t-1,0}(r + \delta^i_t - \zeta^i_t + \delta^i_t \zeta^i_t)$[7]
with

- δ^i_t, the rate of depreciation ($\equiv 1 - \frac{q^i_{t,s+1}}{q^i_{t,s}}$), which corresponds to the loss in market value of a capital good due to ageing. This rate is related to the age-efficiency profile chosen. In the case of geometrically declining efficiency, the depreciation rate is usually the rate used in the construction of the productive capital stock, assuming that the age-price[8] and the age-efficiency profile follow the same geometric pattern (with a constant rate). However, in the case of a hyperbolic pattern, the depreciation rate has to be calculated. We followed the way recommended by the OECD Manual (Annex 5 of "Measuring productivity"), which consists in the calculation of the age-price profile and then the net wealth stock[9].
- ζ^i_t, a revaluation or capital gains term defined as the expected asset price change between the beginning and the end of the period (of a new asset): $\zeta^i_t \equiv \frac{q^i_{t,0}}{q^i_{t-1,0}} - 1$. This term is introduced in the equation with a negative sign, which means that a fall in asset prices raises user costs.
- r, the net rate of return, which corresponds to the expected remaining remuneration for the capital owner once depreciation and asset price changes have been taken into account. There are mainly two approaches to the measurement of the rate of return: an endogenous rate and an exogenous rate.

---

[7] It is a pre-tax measurement of user cost of capital, because there are no tax variables. Some authors leave out the interaction term $\delta^i_t \zeta^i_t$ by simplification. We added a constraint to this equation: the user cost cannot be negative and is set to zero in case of negative value. A negative value can indeed be observed in some cases.

[8] The age-price profile of an asset describes the decline in the price of an asset as it ages. This profile, related to the age-efficiency profile, will be explained in more details in point C "The net and the gross capital stock" of this chapter.

[9] The depreciation rate is obtained by calculating the following equations :

- Calculation of the age-price profile: $z^i_s = \frac{\sum_{\tau}^{T-s} h^i_{\tau+s} . F^i_{\tau+s} . (1.04)^{-(1+\tau)}}{\sum_{\tau}^{T} h^i_{\tau} . F^i_{\tau} . (1.04)^{-(1+\tau)}}$ with s : age of asset

- Calculation of the net wealth capital stock at constant prices: $K^{N,i}_t = \sum_{\tau=0}^{T} z^i_{\tau} . F^i_{\tau} . I^i_{t-\tau}$

- Calculation of the real depreciation: $D^i_t = K^{N,i}_{t-1} - K^{N,i}_t + I^i_t$

- Calculation of the depreciation rate: $\delta^i_t = \frac{D^i_t}{K^{N,i}_t}$

c. The endogenous net rate (ex-post rate)

The endogenous rate of return is calculated as the ex-post rate that exhausts all non-labour incomes computed in the National Accounts. Gross operating surplus plus the capital part of mixed income of self-employed are considered as compensation for capital. The net rate of return r is then computed by solving the following equation:

$$P_t Q_t - w_t L_t = \sum_i uc_t^i K_t^i = r_t \sum_i q_{t-1}^i K_t^i + \sum_i (\delta_t^i - \zeta_t^i + \delta_t^i \zeta_t^i) q_{t-1}^i K_t^i$$

So the rate of return is equal to:

$$r_t = \frac{CAP - \sum_i (\delta_t^i - \zeta_t^i + \delta_t^i \zeta_t^i) q_{t-1}^i K_t^i}{\sum_i q_{t-1}^i K_t^i},$$

with CAP: the capital compensation (gross operating surplus plus the capital part of mixed income)

This method is used by the Australian Bureau of Statistics and the US Bureau of Labour Statistics and requires that the underlying production function exhibits constant returns to scale, that markets are competitive and the expected (ex-ante) rate of return equals the realized (ex-post) rate of return (OECD (2001a)).

An assumption has also to be made to decompose the mixed income of self-employed into labour and capital components. In Belgium, we do not have data on labour compensation for self-employed. In this paper, we estimated this compensation by assuming that the compensation per self-employed person is equal to the compensation per employee. A limit is, however, imposed by sector: the estimated labour compensation for self-employed cannot exceed the mixed income.

d. The exogenous net rate (ex-ante rate)

An alternative is to estimate an exogenous rate from market interest rates that play a key role in determining rates of return. Indeed, the decision to purchase a capital asset is partially based on the comparison between the expected return of the asset and the interest rates from markets. Furthermore, investment in capital assets is often at least partly financed by loans.

To compute an exogenous net rate, we followed the methodology used by Schreyer (2003). The expected nominal interest rate for every year is then computed as:

$$r_t = [(1 + rr)(1 + p_t)] - 1$$

where p is the expected value of the consumer price index and rr a constant value representing the expected real interest rate.

The expected real interest rate rr is computed by taking a series of annual observed nominal rates (un-weighted average of interest rate with different maturities) and deflating them by the consumer price index. The resulting series of real interest rates is averaged over the concerned period to yield a constant value for rr.

To obtain a measurement for p, the expected overall inflation, we construct a 5-year moving average of the rate of change of the consumer price index:

$$MACPI_t = \sum_{s=1}^{5} CPI_{t-s} \Big/ 5$$

where CPI is the rate of change of the consumer price index.

With an ex-ante rate of return, the value of capital services is not necessarily equal to the capital compensation derived from the National Accounts, which makes the growth accounting exercises more difficult.

3.2.2 The volume index of capital services

The aggregation of the different productive stocks of capital assets is made by using the user costs of capital as weights. User costs are prices for capital services and, under competitive markets and equilibrium conditions, these prices reflect the marginal productivity of the different assets. User cost weights thus provide a means to incorporate differences in the productive contribution of heterogeneous investments into the overall measurement of capital input (OECD (2001a)).

A usual and theoretically recommended index formula to construct a volume index of capital services is the Törnqvist index:

$$\ln(K_{t+1}/K_t) = \sum_i 0.5(v_{t+1}^i + v_t^i)\ln(K_{t+1}^i/K_t^i) \qquad \text{where } v_t^i \equiv \frac{uc_t^i K_t^i}{\sum_i uc_t^i K_t^i}$$

3.3 The net and the gross capital stock

The gross capital stock and the net capital stock are measurements of capital that are frequently available, but that do not measure the productive efficiency of the assets. The gross capital stock corresponds to the sum of past investments, corrected only for a retirement pattern. It ignores deterioration of assets with age and it values past investments at "as new" prices. Consequently, the gross capital stock can be considered as a particular case of productive stock, where the efficiency of the assets remains fully unaltered until the end of the service life (which is called a"one-hoss shay" pattern).

The net capital stock, sometimes called the wealth stock, measures the market value of capital assets. It corresponds to the sum of past investments, corrected for retirement and for loss in value due to ageing. This measurement of wealth is published in the balance sheets of the National Accounts. The net stock is usually derived from the gross stock by deducting the consumption of fixed income or depreciation measuring the loss in value of capital goods as it ages. Depreciation has to be distinguished from efficiency decline that reflects the loss of productive efficiency as assets age and that is associated with the productive capital stock.

The net stock can also be derived by first assuming an age-efficiency profile and then by estimating the corresponding age-price profile which describes the change (usually the decline) in the price of an asset as it ages and which is linked to the depreciation concept. Indeed, the net capital stock at constant prices can be obtained by using an age-price profile (z):

$$K_t^{N,i} = \sum_{\tau=0}^{T} z_\tau^i . F_\tau^i . I_{t-\tau}^i$$

with F_τ^i the retirement function and $I_{t-\tau}^i$ the real investment. The age-price profile and the age-efficiency profile of an asset are related, but are not necessarily identical. It will only be identical if the two profiles coincide. The age-price profile can be derived from the age-efficiency profile according to the formula explained in footnote 8. In the case of a geometric age-efficiency profile, it is usually assumed that the efficiency and the market value of the asset decline at a constant rate independent of time, which considerably simplifies the calculations. The age-price profile can also be obtained with other methods such as econometric studies of used asset markets (Hulten and Wykoff (1980)[10]) or by assuming a pattern (OECD (2001b)).
The total value of the net stock is obtained as follows:

$$q_t W_t = \sum_i q_t^i W_t^i \qquad \text{(Schreyer (2003))}$$

With q^i: the market price of the asset i.

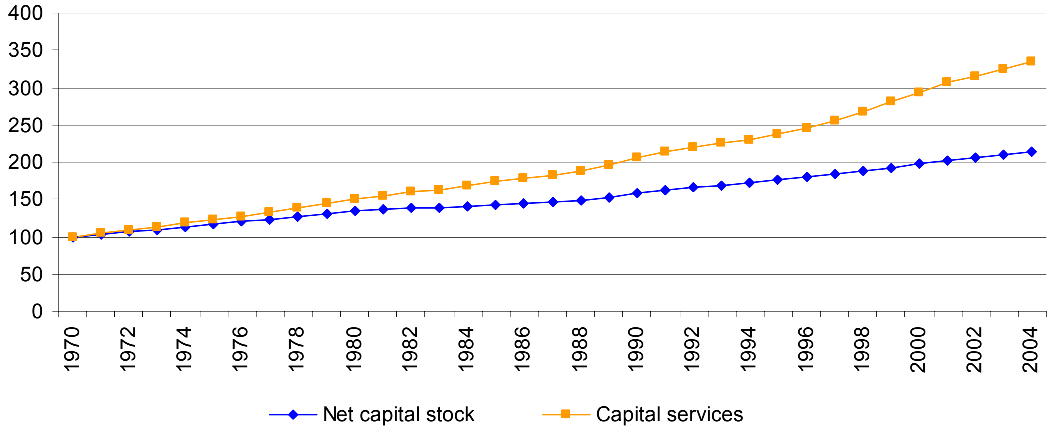
The rate of change of the net stock at constant prices depends on the index number formula chosen for the aggregation of assets. One solution is to use a Törnqvist index:

$$\ln(W_{t+1}/W_t) = \sum_i 0.5(w_{t+1}^i + w_t^i)\ln(W_{t+1}^i/W_t^i) \qquad \text{where } w_t^i \equiv \frac{q_{t,0}^i W_t^i}{\sum_i q_{t,0}^i W_t^i}$$

However, the majority of countries use a Laspeyres-type volume index (Schreyer (2003)).
To illustrate the difference between the net capital stock and the capital services, Figure 6 shows the two measurements for the entire economy. Both measurements are computed with a Törnqvist index. The stocks are based on a geometric pattern, assuming that the efficiency and the market value of the assets decline at the same rate. Schreyer and Pilat (2001) observed that in the empirical applications, the growth rate of capital services is generally higher than the growth

rate of the net capital stock. So, if the net capital stock is used as a measurement of capital input in the productivity analyses, the growth of TFP could be overestimated, compared with TFP growth linked to capital services.

Figure 6: Capital services and net capital stock, Total economy, 1970=100



---

[10] Cited in OECD (2001b).

4 Results

4.1 The data

The different measurements of capital services are realized by using investment data constructed on the basis of the Belgian National Accounts published in November 2006 within the framework of the European EUKLEMS project in which the Federal Planning Bureau is involved. We used official data on investment published either by product (7), or by sector (29) from 1995 to 2004 (at current and constant prices). Then, we used unpublished official data and we made several assumptions, coherent with the National accounts to construct 3 ICT assets, data from 1853 to 2004 and crossing 29 sectors and 9 products and hedonic price indices.

The methodology followed for constructing the data, the descriptions of the 29 sectors covered and the description and the service lives of the 9 products covered are detailed in the annex.

The other data used to estimate the total factor productivity come from the National Bank of Belgium for the period 1995-2004. For the period before 1995, data are estimations made within the framework of the EUKLEMS project, which are compatible with the National Accounts.

4.2 Results

This chapter presents measurements of productive capital stocks, user costs and capital services estimated by means of different methodologies to test the sensitivity of these measurements to methodological changes. Then, by using the results on capital services, the data on hours worked by employees and self-employed and the estimation of the costs shares of inputs, we calculate the contribution of TFP to GDP growth, in order to evaluate the impact of methodological changes on TFP contribution.

4.2.1 The productive capital stock

e. The hyperbolic profile

The hyperbolic productive capital stock is calculated by using a hyperbolic age-efficiency function and a retirement function. As said before, it is possible to choose different options in each of these two functions.

Variation of the parameters of the age-efficiency function

Table 1 presents the productive capital stock in IT equipment (5 years of average service life) for the electrical and optical equipment sector (DL) at different years. The second part of the table provides the average annual growth rate of this stock between these years. Different options are chosen for the maximum service life T and for the β parameter according to practices observed in other papers or literature. The maximum service life T can be equal to the average service life n, to 1.5n and to 2n. The β parameter can be set at 0.5, 0.8, 0.75 and 1. With the β parameter set at 1, the efficiency function is in fact a constant function and with the parameter set at 0, it is a linear function. The retirement function chosen is a normal function for all estimations.

Table 1 shows that the productive capital stock in level increases when the maximum service life and the β parameter increase. A higher value for β means that the asset loses its efficiency more slowly. Variations in productive stocks are higher when the maximum service life changes than when the β parameter changes. Indeed, a maximum service life between n and 2n generates a productive capital stock between 438.1 and 543.2; while, the variation of the β parameter between 0.5 and 0.8 generates a productive capital stock between 452.2 and 510.5. The productive stock obtained with a linear age-efficiency profile is the lowest. The productive stock obtained by using a constant function (β=1) is logically very high compared to the other options. This extreme case, in which the asset does not lose efficiency, is in fact never used, because it does not seem realistic. A similar conclusion can be drawn from the growth rates.

Table 1: Productive capital stock in IT equipment (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Hyperbolic, T=2n, β=0.8	0.4	5.7	97.3	397.4	543.2
Hyperbolic, T=1.5n, β=0.8	0.4	5.5	92.4	380.6	510.5
Hyperbolic, T=n, β=0.8	0.4	5.2	79.9	343.7	438.1
Hyperbolic, T=1.5n, β=0.75	0.4	5.5	90.4	373.6	498.6
Hyperbolic, T=1.5n, β=0.5	0.4	5.2	82.9	345.8	452.2
Linear, T=1.5n, β=0	0.3	4.9	73.5	308.9	393.4
Constant, T=1.5n, β=1	0.4	5.9	103.3	418.6	580.8

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Hyperbolic, T=2n, β=0.8	30.1%	32.9%	32.9%	8.1%	23.5%
Hyperbolic, T=1.5n, β=0.8	30.1%	32.5%	32.5%	7.6%	23.4%
Hyperbolic, T=n, β=0.8	30.2%	31.4%	31.4%	6.3%	23.1%
Hyperbolic, T=1.5n, β=0.75	30.1%	32.4%	32.4%	7.5%	23.4%
Hyperbolic, T=1.5n, β=0.5	30.3%	31.9%	31.9%	6.9%	23.3%
Linear, T=1.5n, β=0	30.6%	31.1%	31.1%	6.2%	23.1%
Constant, T=1.5n, β=1	30.0%	33.2%	33.2%	8.5%	23.6%

Table 2 presents the productive capital stock in other constructions for the same sector. This asset has an average service life of 35 years in this sector. The same observations appear for this asset with a much higher service life.

Table 2: Productive capital stock in other constructions (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Hyperbolic, T=2n, β=0.8	1208.6	1959.2	2671.0	3659.9	3662.4
Hyperbolic, T=1.5n, β=0.8	1172.8	1908.7	2586.5	3524.6	3507.0
Hyperbolic, T=n, β=0.8	1072.5	1769.5	2332.1	3073.3	2972.1
Hyperbolic, T=1.5n, β=0.75	1156.6	1880.5	2538.8	3454.1	3428.7
Hyperbolic, T=1.5n, β=0.5	1091.1	1760.1	2339.6	3167.6	3113.7
Linear, T=1.5n, β=0	1000.5	1581.2	2059.2	2780.4	2691.4
Constant, T=1.5n, β=1	1262.3	2048.5	2821.9	3887.1	3916.6

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Hyperbolic, T=2n, β=0.8	4.9%	3.1%	3.1%	0.0%	3.31%
Hyperbolic, T=1.5n, β=0.8	5.0%	3.1%	3.1%	-0.1%	3.27%
Hyperbolic, T=n, β=0.8	5.1%	2.8%	2.8%	-0.8%	3.04%
Hyperbolic, T=1.5n, β=0.75	5.0%	3.0%	3.0%	-0.2%	3.25%
Hyperbolic, T=1.5n, β=0.5	4.9%	2.9%	2.9%	-0.4%	3.13%
Linear, T=1.5n, β=0	4.7%	2.7%	2.7%	-0.8%	2.95%
Constant, T=1.5n, β=1	5.0%	3.3%	3.3%	0.2%	3.39%

Variation of the profile of the retirement function

Table 3 presents the productive capital stock in IT equipment for the sector DL estimated with different retirement functions. For the parameters of the age-efficiency function, we took usual values for T (=1.5n) and β (=0.8). The two bell-shaped functions (normal and lognormal) generate similar stocks and average growth rates for the considered periods. On the other hand, lower stocks and growth rates are obtained when using the linear retirement function. Given the short average service life of IT equipment, simultaneous exit and delayed linear functions generate identical results, which are higher in level and in growth rate compared to normal retirement.

Table 3: Productive capital stock in IT equipment (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Hyperbolic, T=1.5n, β=0.8, Normal retirement	0.4	5.5	92.4	380.6	510.5
Hyperbolic, T=1.5n, β=0.8, Log normal retirement	0.4	5.5	92.1	381.6	510.3
Hyperbolic, T=1.5n, β=0.8, Simultaneous exit retirement	0.4	5.7	101.1	402.4	555.8
Hyperbolic, T=1.5n, β=0.8, Linear	0.3	4.8	72.7	302.5	387.8
Hyperbolic, T=1.5n, β=0.8, Delayed Linear	0.4	5.7	101.1	402.4	555.8

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Normal retirement	30.1%	32.5%	32.5%	7.6%	23.4%
Hyperbolic, T=1.5n, β=0.8, Log normal retirement	30.1%	32.5%	32.5%	7.5%	23.4%
Hyperbolic, T=1.5n, β=0.8, Simultaneous exit retirement	30.0%	33.3%	33.3%	8.4%	23.6%
Hyperbolic, T=1.5n, β=0.8, Linear	30.8%	31.2%	31.2%	6.4%	23.1%
Hyperbolic, T=1.5n, β=0.8, Delayed Linear	30.0%	33.3%	33.3%	8.4%	23.6%

Table 4 presents the productive capital stock in other constructions for the same sector. The two-bell shaped functions have similar results. For this asset with a higher service life, the simultaneous exit and the delayed linear retirement functions are different, but quite close. Once again, the results are very different when using a linear retirement function.

Table 4: Productive capital stock in other constructions (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Hyperbolic, T=1.5n, β=0.8, Normal retirement	1172.8	1908.7	2586.5	3524.6	3507.0
Hyperbolic, T=1.5n, β=0.8, Log normal retirement	1172.7	1914.4	2603.2	3521.9	3496.2
Hyperbolic, T=1.5n, β=0.8, Simultaneous exit retirement	1176.6	1946.6	2679.5	3731.3	3712.0
Hyperbolic, T=1.5n, β=0.8, Linear	996.8	1542.0	2008.8	2754.2	2677.5
Hyperbolic, T=1.5n, β=0.8, Delayed Linear	1186.2	1945.8	2677.4	3700.4	3662.5

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Normal retirement	5.0%	3.1%	3.1%	-0.1%	3.27%
Hyperbolic, T=1.5n, β=0.8, Log normal retirement	5.0%	3.1%	3.1%	-0.2%	3.27%
Hyperbolic, T=1.5n, β=0.8, Simultaneous exit retirement	5.2%	3.2%	3.2%	-0.1%	3.44%
Hyperbolic, T=1.5n, β=0.8, Linear	4.5%	2.7%	2.7%	-0.7%	2.95%
Hyperbolic, T=1.5n, β=0.8, Delayed Linear	5.1%	3.2%	3.2%	-0.3%	3.37%

f. The geometric profile

With the geometric age-efficiency profile, the value of the productive capital stock depends on the estimation of the depreciation rate. The depreciation rate is usually computed by dividing the declining-balance rates of Fraumeni (1997) by the average service life of the assets. The depreciation rates, that we called gamma 1, correspond to this computation and use the average service lives given by the National Bank of Belgium for non-ICT assets and software. For the other two ICT assets -IT equipment and communications equipment- we followed the assumptions of the US Bureau of Economic Analysis (see Annex C). The depreciation rates gamma 2 are rates used in the European EUKLEMS project for all countries. For ICT assets, these rates are those given by Jorgenson and Stiroh (2000) and Oulton (2001) and are often used by many authors for ICT assets.

Table 5 shows productive capital stock in the ICT asset “IT equipment” for the sector electrical and optical equipment (DL). Gamma 1 is equal to 0.4 and gamma 2 to 0.315. The productive capital stocks and average growth rates in the considered periods are higher with the lower depreciation rate. The same conclusion appears from Table 6 showing the productive capital stocks for other constructions in sector DL. In this sector, gamma 1 is equal to 0.026 and gamma 2 to 0.033.

Table 5: Productive capital stock in IT equipment (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Geometric, gamma 1	0.3	4.0	53.1	224.2	270.9
Geometric, gamma 2	0.3	4.4	62.2	260.8	330.9

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Geometric, gamma 1	31.7%	29.5%	29.5%	4.8%	22.7%
Geometric, gamma 2	31.4%	30.4%	30.4%	6.1%	23.1%

Table 6: Productive capital stock in other constructions (of the electrical and optical equipment sector)

Levels	1970	1980	1990	2000	2004
Geometric, gamma 1	1231.9	1789.2	2312.5	3173.8	3165.7
Geometric, gamma 2	1119.6	1608.7	2059.2	2818.3	2765.8

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1970-2004
Geometric, gamma 1	3.8%	2.6%	2.6%	-0.1%	2.81%
Geometric, gamma 2	3.7%	2.5%	2.5%	-0.5%	2.70%

g. Geometric versus hyperbolic

Figures 7 and 8 compare some results obtained above with hyperbolic, geometric and constant functions for the two assets: IT equipment and other constructions in the electrical and optical equipment sector. In both cases, the productive capital stock estimated by using a hyperbolic age-efficiency profile, combined with a log-normal retirement function (current function), is higher in level than the stock estimated with a geometric function. In the case of the hyperbolic profile, increasing the maximum service life from 1.5n to 2n will generate an even higher productive stock. In both cases, the geometric profile estimated with the EUKLEMS depreciation rates (gamma 2) seems similar to the hyperbolic profile, combined with a linear retirement function. Finally, the constant function generates logically the highest productive capital stock.

For the whole economy and for the majority of assets, the estimation of productive capital stocks is higher in level, when it is realized with a hyperbolic profile (with mean parameters: T=1.5n and β=0.75) than when a geometric profile is assumed. If a maximum service life of 2n and a β parameter of 0.8 are chosen, the hyperbolic estimation is even higher for all assets, except for products of agriculture.

Figure 7: **Hyperbolic versus geometric: Productive capital stock in IT equipment (of the electrical and optical equipment sector)**

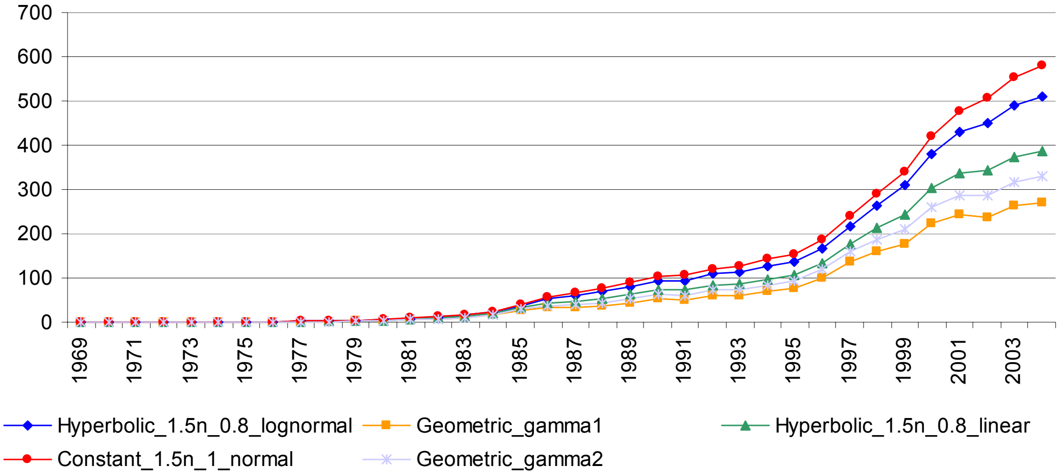
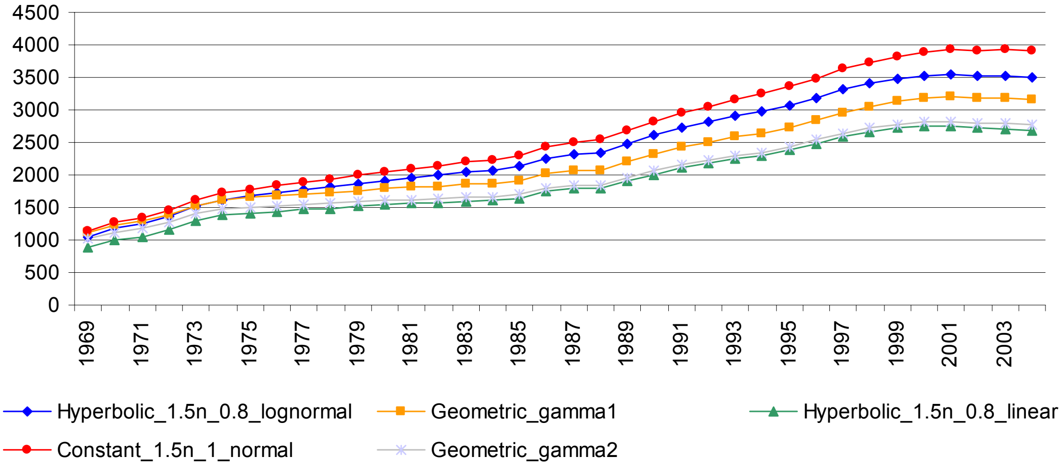


Figure 8: **Hyperbolic versus geometric: Productive capital stock in other constructions (of the electrical and optical equipment sector)**



4.1.2 User costs

The estimation of the user costs of capital depends on several variables: the rate of return which can be computed ex-ante or ex-post, the rate of depreciation which depends on the age-efficiency profile chosen and the revaluation term. So it is possible to use ex-post or ex-ante user costs estimated either with a geometric depreciation rate or a hyperbolic depreciation rate. An ex-post approach is used in the EUKLEMS database.

Figure 9 presents for example, different computations of the rate of return of capital for the whole economy: an ex-ante rate of return (REA) based on the methodology used by Schreyer (2003) and explained before, an ex-post rate of return based on a geometric age-efficiency profile[11] and an ex-post rate based on a hyperbolic age-efficiency profile. It should be noted that these rates do not take into account the fiscal effect created by changes in tax rates on business income. Figure 9 shows that the two ex-post rates of return follow the same evolution, but the hyperbolic rate is systematically below the geometric rate. The three rates of return have declined over the whole period. However, the geometric ex-post rate is frequently above the ex-ante rate and the hyperbolic ex-post rate is frequently below.

Figure 9: Rate of return (for total economy)

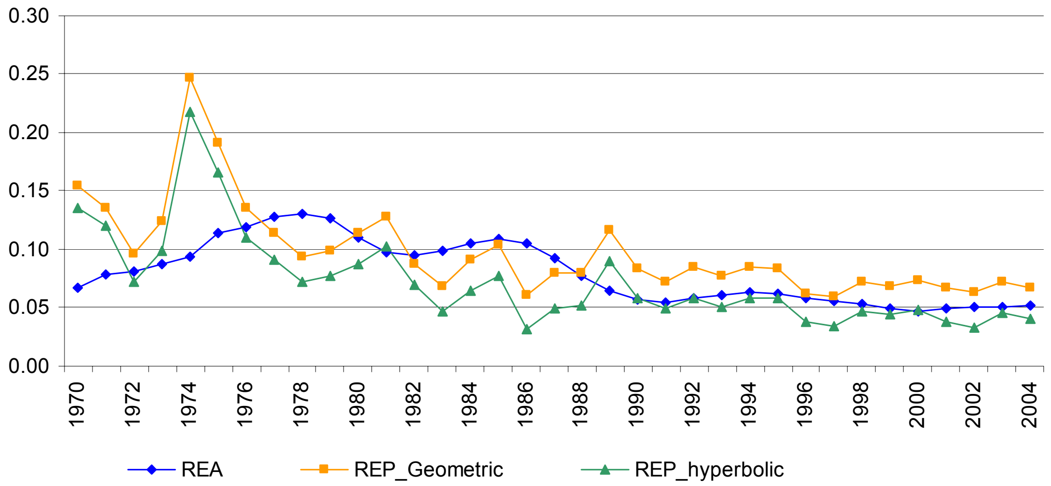


Figure 10 presents the user costs of the asset "other constructions" in the sector DL. These user costs are calculated according to the four assumptions cited above[12]. The evolution of the estimation of the user cost seems to be more influenced by the choice between an ex-post or ex-ante rate of return than by the chosen depreciation profile. Indeed, the two ex-ante estimations and the two ex-post estimations seem to follow a similar evolution. Using the ex-ante method or the ex-post method seems to generate quite different user costs. The two ex-ante estimations, constructed with the same ex-ante rate of return (REA), are similar. This means that the hyperbolic and the geometric depreciation rates are similar for this asset. It is not always the case for the other assets. Figures 10 and 11 show that, on the other hand, the geometric ex-post user cost is always higher than the hyperbolic ex-post user cost. This gap between the user costs is explained in this case by the rate of return. The difference between the ex-ante and ex-post estimations is less pronounced when the user costs are calculated for the whole economy (see figure 11).

---

[11] The choice between gamma 1 and gamma 2 is of no importance because they give practically identical ex-post rates of return.

[12] The hyperbolic profile is combined with a lognormal retirement function (other assumptions: T=1.5n, β=0.8) and the geometric profile is estimated with the euklems depreciation rates (gamma 2).

Figure 10: User cost of the asset "other constructions" (in the electrical and optical equipment sector)

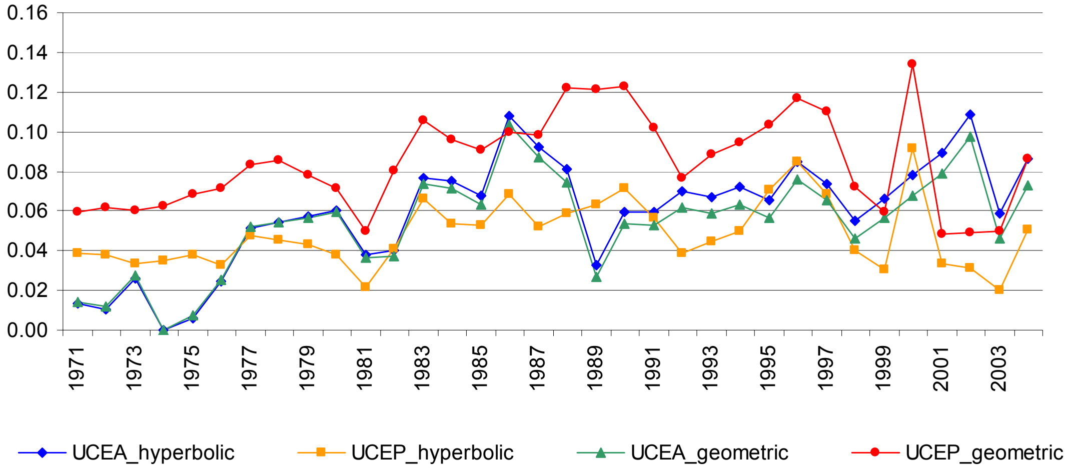
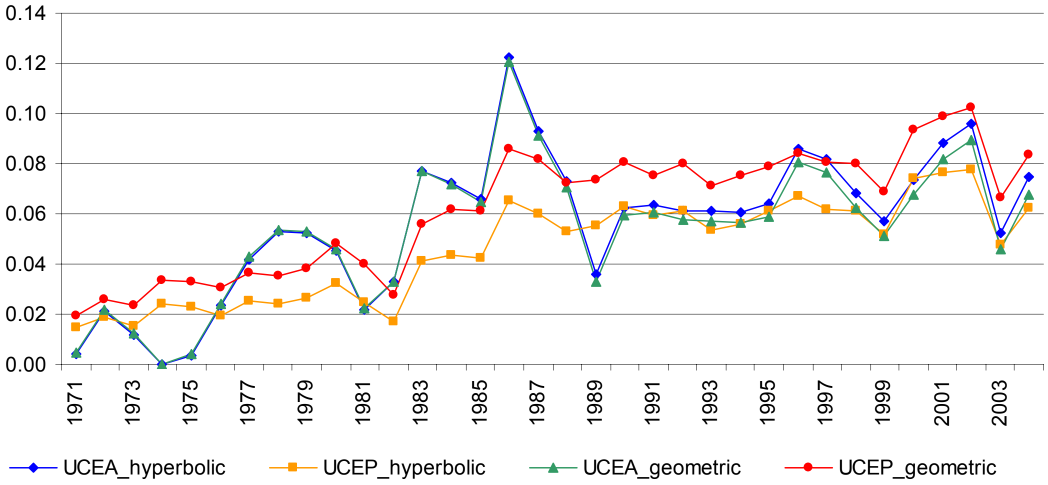


Figure 11: User cost of the asset "other constructions" (for total economy)



4.1.2 Volume index of capital services

Table 7 gives the volume index of capital services (1980=100) of the electrical and optical equipment sector (DL) for several years. Table 8 gives the same results for the total economy. For the hyperbolic estimation, the two more realistic retirement functions have been selected: a bell-shaped function (lognormal), and a delayed-linear function. The base is set to 1980 because important differences between the ex-ante and the ex-post estimation appear in the beginning of the seventies, which influence the whole period if the base is set to 1970. With the base in 1980, it is possible to observe what happens before and after 1980. However, growth rates on the whole period 1970-2004 are also given.

At the end of the considered period, the volume index of capital services takes the lowest value when the linear age-efficiency profile is chosen (with ex-post rate of return) in Table 7 and the geometric pattern (gamma 2) with an ex-post rate of return is chosen in Table 8. It takes the highest value when the geometric profile is selected (ex-ante, gamma 2) in Table 7 and when the hyperbolic profile is selected (ex-post, lognormal) in Table 8. The choice of the age-efficiency profile seems to have an influence on the evolution of the volume index of capital services, but the choice between an ex-ante and an ex-post rate of return seems also important, in particular in the case of a geometric profile for the sector DL.

For the whole economy and the entire period, if an ex-post approach is used, the volume indices of capital services estimated with a hyperbolic age-efficiency profile grow at a higher rate than the indices estimated with a geometric profile, whatever the retirement function (lognormal or delayed-linear) or the geometric depreciation rates (gamma 1 or gamma 2 of the euklems project) chosen. This general conclusion is observed in almost all sectors over the whole period 1970-2004. It is, however, less frequent over the period 1980-2004 (see DL sector in Table 7). It is the linear age-efficiency profile which provides the most similar results to the geometric results. The opposite of this conclusion is observed in both tables with an ex-ante approach: the volume indices grow at a somewhat higher rate when a geometric profile is adopted, but to a lesser extent. Indeed, this is only observed for the whole economy if the considered period is reduced to 1980-2004. The differences observed in indices in the case of an ex-ante approach are more apparent in the DL sector than in the whole economy, where the indices are quite similar.

In the case of a hyperbolic profile, taking a longer maximum service life and/or a higher β parameter increase the value and the growth rate of the volume index of capital services. Indeed, a longer maximum service life and/or a higher β parameter (slower loss of efficiency) generate a higher productive capital stock and growth rate of the stock over the considered period. Concerning the retirement function, the same conclusion appears from the two tables: in 2004, the index is slightly higher in level and in growth rate with a delayed-linear function, then with a lognormal and is the lowest with a linear function (with T=1.5n in each case). In the case of a geometric profile, the choice between the gamma 1 and gamma 2 depreciation rates has no influence on the volume index of capital services for the whole economy. However, differences appear in the indices of sectors (see Table 7).

Table 7: Volume index of capital services (all assets), in the electrical and optical equipment sector (1980=100)

1980=100	1970	1980	1990	2000	2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-ante	43.2	100.0	226.8	406.6	418.5	6.97%
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-post	48.8	100.0	238.9	431.8	441.9	6.76%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-ante	42.8	100.0	229.3	416.0	429.9	7.09%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-post	48.5	100.0	242.6	446.0	458.6	6.90%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-ante	44.3	100.0	224.2	401.6	409.4	6.83%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-post	49.9	100.0	231.5	414.1	419.7	6.53%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-ante	42.3	100.0	233.0	407.3	420.4	7.06%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-post	48.2	100.0	244.4	429.2	442.2	6.80%
Linear, T=1.5n, β=0, Lognormal, ex-ante	45.7	100.0	223.0	399.6	402.5	6.69%
Linear, T=1.5n, β=0, Lognormal, ex-post	51.5	100.0	224.5	397.7	398.5	6.28%
Geometric, gamma 1, ex-ante	47.8	100.0	253.0	478.5	484.4	7.19%
Geometric, gamma 1, ex-post	54.8	100.0	231.9	417.4	420.5	6.29%
Geometric, gamma 2, ex-ante	48.9	100.0	262.5	517.7	513.8	7.28%
Geometric, gamma 2, ex-post	55.5	100.0	239.0	449.3	445.3	6.42%

Table 8: Volume index of capital services (all assets), total economy (1980=100)

1980=100	1970	1980	1990	2000	2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-ante	60.4	100.0	136.6	198.8	230.5	4.03%
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-post	62.1	100.0	139.7	205.5	239.7	4.06%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-ante	60.2	100.0	137.2	199.8	231.9	4.05%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-post	62.0	100.0	140.6	207.3	242.2	4.09%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-ante	60.9	100.0	135.5	196.9	227.7	3.96%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-post	62.7	100.0	137.8	201.3	233.6	3.95%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-ante	59.9	100.0	137.5	200.3	232.6	4.08%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-post	61.9	100.0	140.5	206.6	241.2	4.08%
Linear, T=1.5n, β=0, Lognormal, ex-ante	61.6	100.0	134.4	195.1	225.0	3.89%
Linear, T=1.5n, β=0, Lognormal, ex-post	63.5	100.0	135.8	196.6	226.8	3.82%
Geometric, gamma 1, ex-ante	62.0	100.0	138.2	201.9	232.5	3.97%
Geometric, gamma 1, ex-post	66.4	100.0	136.9	195.4	222.7	3.63%
Geometric, gamma 2, ex-ante	62.0	100.0	138.2	202.0	232.7	3.97%
Geometric, gamma 2, ex-post	66.3	100.0	136.6	194.9	222.0	3.62%

4.1.3 Total factor productivity growth

The estimation of the rate of change of the volume index of capital services allows to assess the TFP residual. Table 9 shows TFP contribution to growth in the electrical and optical equipment sector for five periods and for the whole period. Table 10 shows the same results for the total economy. Those two tables allow to evaluate more easily whether the variations of volume index of capital services linked to methodological changes are really significant. Over the period 1970-2004, tfp growth is comprised between 2.64% (Geometric, gamma 2, ex-ante) and 2.91% (Geometric, gamma 1, ex-post and linear ex-post) in the electrical and optical equipment sector and between 1.07% (hyperbolic profiles) and 1.23% (geometric, gamma 1 and 2 ex-post) in the whole economy. The results in each table are therefore relatively similar over long periods of time, even if, for the whole economy, TFP based on the ex-post approach grows on average at a slightly higher rate when a geometric age-efficiency profile is adopted. This higher TFP contribution is due to a lower capital contribution resulting from a lower growth rate of the volume index of capital services. The opposite is observed in both tables with an ex-ante approach: TFP grows on average at a somewhat higher rate when a hyperbolic age-efficiency profile is adopted. This is, however, only the case for the whole economy if the average annual rate is computed for the shorter period 1980-2004.

Over shorter periods, like the last period 2000-2004, the different methodologies generate more significant variations of TFP contribution. Over the recent period 2000-2004, the TFP contribution for the whole economy is estimated between 0.04% and 0.27%, when the estimation is respectively realized with a hyperbolic age-efficiency profile (T=2n, β=0.8) combined with a, lognormal retirement function and an ex-post rate of return and with an ex-post geometric profile (gamma 2). It also appears that, for the whole economy, the variations in TFP contribution are larger when an ex-post user cost is used.

In the case of a hyperbolic profile, a longer maximum service life and/or a higher β parameter decrease the contribution of TFP. Indeed, a longer maximum service life and/or a higher β parameter (slower loss of efficiency) generate a higher growth rate of the volume index of capital services and thus a higher capital contribution. In the case of a geometric profile, the choice between the gamma 1 and gamma 2 depreciation rates has no influence on the TFP contribution for the total economy. However, differences appear in the TFP growth of sectors (see Table 7).

Table 9: TFP contribution to growth, electrical and optical equipment sector

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1980-2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-ante	4.23%	0.88%	4.03%	0.18%	2.08%	2.71%
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-post	4.65%	0.74%	4.01%	0.20%	2.01%	2.79%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-ante	4.20%	0.85%	4.00%	0.16%	2.05%	2.68%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-post	4.63%	0.70%	3.96%	0.18%	1.97%	2.75%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-ante	4.31%	0.91%	4.03%	0.23%	2.10%	2.75%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-post	4.71%	0.83%	4.04%	0.25%	2.07%	2.84%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-ante	4.16%	0.81%	4.10%	0.16%	2.07%	2.69%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-post	4.61%	0.68%	4.08%	0.17%	2.01%	2.78%
Linear, T=1.5n, β=0, Lognormal, ex-ante	4.40%	0.91%	4.03%	0.29%	2.11%	2.78%
Linear, T=1.5n, β=0, Lognormal, ex-post	4.79%	0.90%	4.07%	0.31%	2.12%	2.91%
Geometric, gamma 1, ex-ante	4.56%	0.52%	3.89%	0.26%	1.88%	2.67%
Geometric, gamma 1, ex-post	4.99%	0.78%	4.03%	0.28%	2.05%	2.91%
Geometric, gamma 2, ex-ante	4.63%	0.43%	3.77%	0.36%	1.81%	2.64%
Geometric, gamma 2, ex-post	5.01%	0.70%	3.91%	0.37%	1.98%	2.87%

Table 10: TFP contribution to growth, total economy

Average annual growth rates	1970-1980	1980-1990	1990-2000	2000-2004	1980-2004	1970-2004
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-ante	2.54%	1.01%	0.11%	0.11%	0.48%	1.09%
Hyperbolic, T=1.5n, β=0.8, Lognormal, ex-post	2.66%	0.93%	0.07%	0.06%	0.42%	1.08%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-ante	2.53%	0.99%	0.10%	0.10%	0.47%	1.08%
Hyperbolic, T=2n, β=0.8, Lognormal, ex-post	2.65%	0.91%	0.06%	0.04%	0.41%	1.07%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-ante	2.58%	1.03%	0.11%	0.13%	0.50%	1.11%
Hyperbolic, T=1.5n, β=0.5, Lognormal, ex-post	2.69%	0.98%	0.09%	0.10%	0.46%	1.12%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-ante	2.51%	0.99%	0.10%	0.10%	0.47%	1.07%
Hyperbolic, T=1.5n, β=0.8, Del. linear, ex-post	2.65%	0.91%	0.07%	0.05%	0.42%	1.07%
Linear, T=1.5n, β=0, Lognormal, ex-ante	2.62%	1.06%	0.11%	0.16%	0.52%	1.13%
Linear, T=1.5n, β=0, Lognormal, ex-post	2.73%	1.03%	0.12%	0.16%	0.50%	1.16%
Geometric, gamma 1, ex-ante	2.64%	0.96%	0.09%	0.17%	0.47%	1.10%
Geometric, gamma 1, ex-post	2.90%	1.00%	0.17%	0.26%	0.53%	1.23%
Geometric, gamma 2, ex-ante	2.64%	0.96%	0.09%	0.17%	0.47%	1.10%
Geometric, gamma 2, ex-post	2.89%	1.01%	0.18%	0.27%	0.54%	1.23%

5. Conclusions

After a theoretical presentation of the different methodologies currently used to construct a volume index of capital services and following the recommendations of the two OECD Manuals (2001a, 2001b), this paper provides results for Belgium over the period 1970-2004. In Belgium, as in many other countries, no official data on flows of capital services exist. However, according to the OECD Manuals, this is the appropriate measurement for productivity studies. In this paper, the capital services are constructed according to the main currently recommended methodologies in order to test the sensitivity of measuring capital services to methodological choices. We also evaluated the impact of the different capital services estimates on the measurement of the total factor productivity contribution to GDP, calculated as residual in the growth accounting approach and providing an estimator of the impact of innovation on the economic growth.

The measurement of the capital services is realized in two steps. First, productive capital stocks have to be estimated for each type of investment goods called assets. Then, these stocks are aggregated with the user costs of capital as weights to derive a global index measuring the productive contribution of all types of capital assets to output growth. Two methodologies are generally used to construct productive capital stocks: the geometric profile and the hyperbolic profile. For each profile, several assumptions have to be made such as the choice of the functional form of the retirement function or of the maximum service life. For the computation of the user costs, we have the choice between an ex-ante and an ex-post rate of return of capital.

The results show that for the whole economy and for the majority of capital assets, the estimation of productive capital stocks is higher in level, when it is computed with a hyperbolic age-efficiency profile (with mean parameters: $T=1.5n$ and $\beta=0.75$) than when a geometric profile is assumed. The growth rates of productive stocks are also higher. The different methodological options within each age-efficiency profile also have consequences on productive capital stocks. With a hyperbolic age-efficiency profile, productive capital stock increases in level and in growth rate, when the maximum service life (T) and the β parameter increase. A higher value for β means that the asset looses its efficiency more slowly. With a geometric profile, productive capital stocks and average growth rates are higher with a lower depreciation rate.

Concerning the user costs of capital, the evolution of the estimation seems to be more influenced by the choice between an ex-post and an ex-ante rate of return than by the assumed depreciation profile (geometric or hyperbolic).

For the whole economy and the entire period, if an ex-post approach is used, the volume indices of capital services estimated with a hyperbolic age-efficiency profile grow at a higher rate than the same indices estimated with a geometric profile, whatever the retirement function (log-normal or delayed-linear) or the geometric depreciation rates (gamma 1 or gamma 2 of the EUKLEMS project) chosen. This general conclusion is observed in almost all industries over the whole period 1970-2004. The opposite is observed with an ex-ante approach: the volume indices grow at a somewhat higher rate when a geometric profile is adopted, but to a lesser extent. Indeed, this observation depends on the studied period. The differences observed in indices in the case of an ex-ante approach are more apparent in the analyzed DL sector than in the whole economy, where the indices are quite similar. In the case of a hyperbolic profile, a longer maximum service life and/or a higher β parameter (slower loss of efficiency) increase the volume index of capital services in level and in growth rate. Concerning the retirement function, the growth rates of indices are slightly higher with a delayed-linear function, than with a lognormal and are the lowest with a linear function. In the case of a geometric profile, the choice between the gamma 1 and gamma 2 depreciation rates has no influence on the volume index of capital services for the total economy. However, differences appear in the volume indices of industries.

The estimation of the change rate of the volume index of capital services allows to assess the contribution of capital and TFP to output growth. TFP contribution estimated with different volume indices of capital services based on different methodologies are relatively similar in the long run, even if for the whole economy, TFP based on the ex-post approach grows on average at somewhat higher rates when a geometric age-efficiency profile is adopted. These higher rates for TFP are due to a lower contribution of capital resulting from a lower growth rate of the volume index of capital services. The opposite is generally observed with an ex-ante approach: TFP grows at somewhat higher rates when a hyperbolic age-efficiency profile is adopted, but to a lesser extent.

Over shorter periods, the different methodologies generate more significant variations of TFP contribution. Over the recent period 2000-2004, the average annual TFP contribution for the whole economy is estimated between 0.04% and 0.27%, when the estimation is respectively realized with a hyperbolic age-efficiency profile (T=2n, β=0.8) combined with a lognormal retirement function and an ex-post rate of return and with an ex-post geometric profile (gamma 2). It also appears that, for the whole economy, the variations in TFP contribution are larger when an ex-post user cost is used. In the case of a hyperbolic profile, a longer maximum service life and/or a higher β parameter decrease the contribution of TFP, given that they generate a higher growth rate of volume index of capital services and such, a higher capital contribution. In the case of a geometric profile, the choice between the gamma 1 and gamma 2 depreciation rates has no influence on the TFP contribution for the whole economy. However, differences appear in the TFP growth of sectors.

In summary, this sensitivity analysis shows that methodological choices have certain consequences on the volume index of capital services and consequently on the estimation of the TFP contribution to growth. These consequences are more important when the analysis is realized at the industry level and when the studied period is short, underlying the importance of long-term perspective to analyze productivity evolution. It seems credible that the appropriate age-efficiency profile differs according to the kind of assets and the industry in which these assets are used. Empirical studies on age-efficiency and retirement profiles of assets are necessary to determine the best appropriated profiles.

References

Bureau of Labor Statistics, (2006), “Overview of Capital Inputs for the BLS Multifactor Productivity Measures”, July.

Erumban A. A., (2004), “Twenty Ways to Aggregate Capital: Does it really Matter for a Study of Economic Growth ?”, August.

Fraumeni B., (1997), “The Measurement of Depreciation in the U.S. National Income and Product Accounts”, Survey of Current Business, July.

Hulten C. R., (1990), “The Measurement of Capital”, in Berndt, Ernst R. and Jack Triplett (eds.) Fifty Years of Economic Measurement, University of Chicago Press.

Inkaar R., O’Mahony M., Timmer M. P., (2005), “ICT and Europe's Productivity Performance: Industry-Level Growth Account Comparisons with the United States”, Review of Income and Wealth, Vol. 51, No. 4, December.

Institut des Comptes nationaux (2006), “Comptes nationaux, Partie 2 – Comptes détaillés et tableaux 1995-2005”, Banque national de Belgique, Bruxelles.

Iommi M., Jona-Lasinio C. (2005), “Alternative estimates of capital input in productivity measures. A sensitivity analysis for the Italian economy over 1990-2003”, Paper prepared for the OECD Workshop on Productivity Measurement, October.

Jorgenson D.W., Stiroh K.J., (2000), “Raising the Speed Limit: U.S. Economic Growth in the Information Age”, Brookings Papers on Economic Activity, n° 1.

Mas M., Pérez F., Uriel E., (2006), “Capital Stock in Spain, 1964-2002, New Estimates”, in “Growth, Capital and New Technologies”, Fundacion BBVA, Bilbao.

OECD (2001a), “Measuring Capital – OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services”, Paris.

OECD (2001b), “Measuring Productivity – OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth”, Paris.

OECD (2005), “Working Party on Indicators for the Information Society, Guide to measuring the Information Society”, DSTI/ICCP/IIS(2005)6/FINAL, November.

O’Mahony M., de Boer W., (2002), “Britain’s relative productivity performance: Updates to 1999”, National Institute Economic Review, Issue 179, January.

Oulton N. (2001), “ICT and productivity growth in the UK”, Bank of England Working Paper, July.

Pamukçu T., Van Zandweghe W., (2002), “Constructing Productive ICT Capital Stock Series for Belgium”, Federal Planning Bureau Working Paper 12-02, October.

Schreyer, P. (2001), “Computer price indices and international growth and productivity comparisons”, OECD Statistics Directorate, National accounts division.

Schreyer P., (2003), “Capital stocks, Capital services and multi-factor productivity measures”, OECD Economic Studies n° 37, 2003/2.

Schreyer P., Pilat D., (2001), “Mesurer la productivité”, Revue économiques de l’OCDE n°33, 2001/11.

Schreyer P., Diewert W. E., Harrison, A., (2005), “Cost of Capital Services and the National Accounts”, STD/NAES(2005)17, September.

Schreyer P., Dupont J., (2006), "OECD Capital Services Estimates: Methodology and a First Set of Results", in "Growth, Capital and New Technologies", Fundacion BBVA, Bilbao.

Solow R.M., (1957), "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, vol. 39, n°2, August.

Van Ark B., Melka J., Mulder N., Timmer M., Ypma G. (2002), "ICT Investments and Growth Accounts for the European Union 1980-2000", Research Memorandum GD-56, Groningen Growth and Development Centre, September.

Wolfl A., and Hajkova D., (2006), "Measuring multifactor productivity growth", Paper Prepared for the 29th General Conference of The International Association for Research in Income and Wealth, August.

Annex

A.1 Description of the sectors

Code NACE Rev1	Description	CPA Reference
AA	Agriculture, hunting and forestry	A
BB	Fishing	B
CA	Mining and quarrying of energy producing materials	CA
CB	Mining and quarrying except energy producing materials	CB
DA	Food products, beverages and tobacco	DA
DB	Textiles and textile products	DB
DC	Leather and leather products	DC
DD	Wood and wood products	DD
DE	Pulp, paper and paper products; publishing and printing	DE
DF	Coke, refined petroleum products and nuclear fuel	DF
DG	Chemicals, chemical products and man-made fibres	DG
DH	Rubber and plastic products	DH
DI	Other non metallic mineral products	DI
DJ	Basic metals and fabricated metal products	DJ
DK	Machinery and equipment n.e.c.	DK
DL	Electrical and optical equipment	DL
DM	Transport equipment	DM
DN	Manufacturing n.e.c.	DN
EE	Electricity, gas and water supply	E
FF	Construction	F
GG	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	G
HH	Hotel and restaurant	H
II	Transport, storage and communication	I
JJ	Financial intermediation	J
KK	Real estate, renting and business activities	K
LL	Public administration and defence, compulsory social security	L
MM	Education	M
NN	Health and social work	N
OO	Other community, social and personal service activities	O
PP	Private households with employed persons	P
QQ	Extra-territorial organisations and bodies	Q

A.2 Description of the assets

Code	Description	CPA Reference
1	Products of Agriculture, hunting, forestry and fishing	01+ 02+ 05
	Equipment:	
2	- Metal Products and Machinery	28 to 33 + 36, except CPA references of IT and communications equipment.
3	- Transport Materials	34 + 35
	Construction:	45
4	- Residential buildings	
5	- Other constructions	
6	Other products	All other assets
7	Software	72
8	IT equipment[13]	300, 321, 332, 333
9	Communications equipment[14]	313,322, 323

---

[13] OECD definition of IT equipment from "Working Party on Indicators for the Information Society, Guide to Measuring the Information Society, DSTI/ICCP/IIS(2005)6/FINAL, November 2005".

[14] OECD definition of Communications equipment.

A.3 Average service life of assets by industry

For the products 1 to 7, the average service lives are those used in the Belgian National Accounts. For the products 8 and 9 (IT and communications equipment), which have been created, the average service lives follow the assumptions of the US Bureau of Economic Analysis.

Industry	P1	P2 before 1985	P2 after 1985	P3	P4	P5	P6	P7	P8	P9
Agriculture, hunting and forestry	3	15	15	12	60	37	8	3	5	11
Fishing	3	15	15	25	60	39	7	3	5	11
Mining and quarrying of energy producing materials	3	20	20	10	60	33	14	3	5	11
Mining and quarrying except energy producing materials	3	28	20	10	60	34	15	3	5	11
Food products, beverages and tobacco	3	28	19	10	60	38	22	3	5	11
Textiles and textile products	3	28	18	10	60	38	22	3	5	11
Leather and leather products	3	29	18	10	60	45	20	3	5	11
Wood and wood products	3	29	19	10	60	45	20	3	5	11
Pulp, paper and paper products; publishing and printing	3	37	18	10	60	38	21	3	5	11
Coke, refined petroleum products and nuclear fuel	3	32	18	10	60	34	21	3	5	11
Chemicals, chemical products and man-made fibres	3	32	17	10	60	34	21	3	5	11
Rubber and plastic products	3	32	19	10	60	30	19	3	5	11
Other non metallic mineral products	3	32	21	10	60	35	19	3	5	11
Basic metals and fabricated metal products	3	32	19	10	60	35	19	3	5	11
Machinery and equipment n.e.c.	3	32	19	10	60	35	19	3	5	11
Electrical and optical equipment	3	32	18	10	60	35	19	3	5	11
Transport equipment	3	32	18	10	60	35	19	3	5	11
Manufacturing n.e.c.	3	32	25	10	60	42	19	3	5	11
Electricity, gas and water supply	3	20	20	10	60	42	19	3	5	11
Construction	3	15	15	8	60	40	7	3	5	11
Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	3	15	15	8	60	40	7	3	5	11
Hotel and restaurant	3	15	15	15	60	40	7	3	5	11
Transport, storage and communication	3	15	15	8	60	40	7	3	5	11
Financial intermediation	3	15	15	8	60	40	7	3	5	11
Real estate, renting and business activities	3	15	15	8	60	(a)	7	3	5	11
Public administration and defence, compulsory social security	3	15	15	8	60	(a)	7	3	5	11
Education	3	15	15	8	60	40	7	3	5	11
Health and social work	3	15	15	8	60	40	7	3	5	11
Other community, social and personal service activities	3	15	15	8	60	40	7	3	5	11
Private households with employed persons	3	15	15	8	60	40	7	3	5	11

(a): 60 years for purchased buildings and buildings constructed by own means, 65 years for roads, 70 years for sea and river works, and 60 years for other construction works.

A.4 Data construction and assumptions

A.4.1 Construction of long investment series crossing sectors and products

The data were constructed in the framework of the European EUKLEMS project in which the Federal Planning Bureau is involved.

The data are constructed from several assumptions in order to be coherent with the revision of National Accounts (published in November 2006[15]) and in order to have 3 ICT assets (in Belgium, there is only one ICT asset in the National Accounts – the software-, starting in 1995). For the construction of the data, we used published revised investment data either by product (7), or by sector (29) from 1995 to 2005, unpublished revised and non-revised SUT investment tables and non-revised historical data crossing 29 sectors and 6/7 assets. Constructed data cover the period 1853-2004 at constant prices and the period 1970-2004 at current prices and cross 29 sectors and 9 products.

A.4.2 Construction of investment series in IT and communications equipment

h. Construction of macro investment series

The method used for the construction of investment expenditure on IT and communications equipment is identical. This method has already been used by Pamukçu and Van Zandweghe (2002) for Belgium. Macroeconomic investment series are obtained indirectly, starting from the condition that domestic supply equals domestic use:

$$Q_{it} + M_{it} - X_{it} + W_{it} + (T_{it}-S_{it}) = CJ_{it} + C_{it} + I_{it} + DS_{it}$$

With Q_{it}, M_{it} and X_{it} respectively standing for domestic production, imports and exports of the asset (domestic supply); $W_{i}t$, $(T_{it}-S_{it})$ standing for margins and net taxes (accounting for the fact that total supply is measured at basic prices whereas use is measured at acquisition prices); CJ_{it}, C_{it}, I_{it} and DS_{it} denoting intermediate consumption, final consumption, investment and change in stocks (domestic use).

For the period 1995-2004, we have revised investment by SUT products. Consequently, for these years, we can estimate IT and communications equipment investment. We used OECD definitions (2005)[16]:

IT equipment (CPA):

- 300 Office, accounting and computing machinery
- 321 Electronic valves and tubes and other electronic components

---

[15] Institut des Comptes nationaux (2006).

[16] We used the definition of ICT manufactured goods and disregarded investment in ICT services through lack of data, except investment in software.

- 332 Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
- 333 Industrial process control equipment

Communications equipment (CPA):

- 313 Insulated wires and cable
- 322 Television and radio transmitters and apparatus for line telephony and line telegraphy
- 323 Television and radio receivers, sound and video recording or reproducing apparatus and associated goods

For the period before 1995, estimates of IT and communications equipment investment were calculated by adjusting domestic supply by the amount of investment per euro of domestic supply in 1995:

$$I_{it} = \frac{I_{i,1995}}{Q_{i,1995} + M_{i,1995} - X_{i,1995}} \left(Q_{it} + M_{it} - X_{it}\right)$$

The foreign trade data used to approximate ICT investment come from the NBB for the period 1995-2004. Then, we used the growth rates of data from the OECD International Trade in Commodities Statistics (ITCS) to construct series from 1961 onwards. Domestic production data come from the NIS (Prodcom) for the period 1995-2004 and are retropolated using the growth rates of imports. Retropolations before 1961 are based on the American growth rate of ICT investments.

i. Construction of sectoral investment series

The only years for which data on ICT investment are available on a sectoral basis are 1995 (non-revised data), 2000 (non-revised data), 2001 and 2002. A RAS-procedure was applied to make the 1995 and 2000 investment matrices compatible with the revised data. To construct investment series at the sector level, we calculated the share of IT equipment investment in total investment in product Pi2 (Metal products and machinery) and the share of communications equipment investment in investment in Pi2 for these years. Then, we multiplied the shares for 1995 by the investment in Pi2 for the years from 1955 to 1994 and the shares for 2002 by the investment in Pi2 for the years from 2003 to 2004. For the years between 1995 and 2000, ICT investments are based on a linear estimation of the shares of ICT investment in product Pi2. Retropolations before 1955 are based on the average growth rate of the data by sector during the last five available years. However, the amounts concerned are very small.

A.4.3 Construction of software investment series

j. Construction of macro investment series

Revised data on software investment cover the period 1995-2004 and are available by sector.

To retropolate software series, it is not possible to use the methodology applied for IT and communications equipment because no trade data are available for this asset. We used the average growth rate over the period 1961-1994 of the ratio between software and hardware investment in US (data from BEA) and the growth of the calculated IT equipment series in Belgium.

k. Construction of sectoral investment series

Software investment series on the period 1961-1994 was divided by sector according to the same distribution as in 1995. A correction had to be applied so that the software investment does not exceed the investment in Pi6 (other products) which contains investment in software on the period 1961-1994.

A.4.4 Harmonized price data

The ICT investment series are constructed in nominal terms. Since no hedonic price indices are available for ICT assets in Belgium, we used the US hedonic price indices to calculate ICT investment series in constant prices. The method that we applied is one of the three methods proposed by Schreyer (2001) and already used by Pamukçu and Van Zandweghe (2002) for Belgium.

The ICT price index for Belgium is calculated as follows:

$$\Delta\tilde{p}_{ICT}^{B} = \Delta p_{OTH}^{B} + \left(\Delta p_{ICT}^{US} - \Delta p_{OTH}^{US}\right)$$

with $\tilde{p}_{ICT}^{B}$ the logarithm of the “harmonized” price index of ICT goods in Belgium.

In order to make the harmonized price index of ICT goods in Belgium independent of the overall price levels in both countries, the price index of non-ICT capital goods in Belgium is corrected by the price index differential of US ICT and non-ICT investment goods.

However, the drawback of this method is that the price indexes of non-ICT capital goods in Belgium and in US are not available and must be approximated by a price deflator of private fixed investment that combines price indices of both ICT and non-ICT investment goods.

Papers issued in the series of the EU KLEMS project

All papers are available in pdf-format on the internet: http://www.euklems.net/

No.1 Mas, Matilde and Javier Quesada, ICT and Economic Growth in Spain 1985-2002 (January 2005)

No.2 Jalava, Jukka, Growth and Productivity in the Finnish Trade Industry, 1975-2003: A National Comparative Perspective (January 2005)

No. 3 Milana, Carlo, The Theory of Exact and Superlative Index Numbers Revisited (March 2005)

No. 4 Jalava, Jukka, Matti Pohjola, Antti Ripatti and Jouko Vilmunen, Biased Techonological Change and Capital-labour Substitution in Finland, 1902-2003 (March 2005)

No. 5 Oulton, Nicholas, Ex Post versus Ex Ante Measures of the User Cost of Capital (August 2005)

No. 6 Görzig, Bernd, Martin Gornig and Axel Werwatz, Firm Specific Wage Spread in Germany -Decomposition of regional differences in inter firm wage dispersion (September 2005)

No. 7 Van Ark, Bart and Robert Inklaar, Catching Up or Getting Stuck? Europe's Problems to Exploit ICT's Productivity Potential (September 2005)

No. 8 Aulin-Ahmavaara, Pirkko and Perttu Pakarinen, Industry Level and Aggregate Measures of Productivity Growth with Explicit Treatment of Taxes on Products (December 2005)

No. 9 Corrado, Carol, Paul Lengermann, Eric J. Bartelsman and J.Joseph Beaulieu, Modeling Aggregate Productivity at a Disaggregate Level: New Results for U.S. Sectors and Industries (July 2006)

No. 10 Ypma, Gerard and Bart van Ark, Employment and Hours Worked in National Accounts: A Producer's View on Methods and a User's View on Applicability (August 2006)

No. 11 Milana, Carlo, Measurement Problems with Non-Invariant Economic Index Numbers of Outputs, Inputs, and Productivity: The Case of Italy (August 2006)

No. 12 Mas, Matilde, Infrastructures and ICT: Measurement Issues and Impact on Economic Growth (December 2006)

No. 13 Biatour, Bernadette, Geert Bryon and Chantal Kegels, Capital Services and Total Factor Productivity Measurements: Impact of Various Methodologies for Belgium (March 2007)

EU KLEMS WORKING
PAPER SERIES