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The Measurement of Capital Services in the Czech Republic

Dana Hájková *

Abstract

When the contribution of capital to aggregate production is to be quantified, a measure of capital services should be used. In this paper I present two experimental measures of capital services for the Czech economy using the OECD methodology. These measures use information on the structure of capital assets by asset type and by the industry in which the capital is used. They weight the contributions of different types of assets by their marginal product instead of by their price, which is the case when using the net capital stock. The analysis shows that growth in the net capital stock, if used as an input into the production function, underestimates the growth of capital input especially in periods of strong investment in highly productive capital assets.

JEL Codes: E23, O11, O12, O47.
Keywords: Capital services, growth accounting, production function, total factor productivity.

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Nontechnical Summary

This paper describes the calculation of an index of capital services in the Czech Republic. This measure captures the flow of the contribution of capital factor input to production and has been used in the CNB for modelling the supply side of the Czech economy. It is methodologically more suitable for this purpose than an index of the capital stock, since it explicitly uses the flow instead of the stock, accounts for the heterogeneity of capital assets and employs a more appropriate set of weights for different types of capital assets.

In principle, the OECD methodology is followed for the construction of the index, but it is simplified to fit the available data. According to the OECD methodology, the capital services of an asset of particular type and age derive in certain proportion from the productive capital stock levels of these assets, adjusted for the loss of productive ability as the asset ages and some probability of retirement throughout the asset's life. The flows of services of particular asset types are then aggregated using as a weight their marginal product, which is approximated by user cost.

Due to the still rather short time-span of publicly available capital formation data in the Czech Republic, the productive capital stocks of particular types of assets are in this paper approximated by measures of the net capital stock at replacement cost from the Czech Statistical Office. The user costs are calculated following the OECD methodology. Two alternative indices of capital services are computed, one based on the type breakdown and the other based on the industry breakdown of the capital assets.

The analysis covers the period 1995–2008. The estimated growth rate of capital services is on average higher than the growth rate of the net capital stock. This means that measuring the capital contribution to production by the net capital stock would, on average, underestimate the productive capital input contribution to growth in the analysed period. The difference between the measures of capital services and the capital stock is primarily structural. Capital services measures give more weight to more productive capital assets, namely transport equipment, other machinery and equipment assets and software if the asset-type breakdown is used, and industry and transport if the industry-type breakdown is used. The developments of the two new alternative indices of capital services are to some extent different, however. The growth rate of the capital services measure based on asset decomposition is in all years higher than the growth rate of the net capital stock. The measure of capital services based on the industry decomposition shows a somewhat different trend and is higher than the capital stock-based measure in the period up to 2003, after that, these latter two measures roughly converge. The difference vanishes mainly due to fading heterogeneity of productive capital stock growth rates towards the end of the sample.

A simple growth accounting exercise employing alternatively the two measures of capital services and a measure of the net capital stock to account for the factor-input growth contribution shows that multi-factor productivity growth could be overestimated if the measure of net capital stock is used. The error is 0.3–0.4 percentage points on average per year in the period 1997–2007, but diminishes towards the end of the period covered.

1. Introduction

In the context of evaluating multi-factor productivity (MFP), proper measurement of all input and output variables is essential. This was emphasized in the seminal contribution by Jorgenson and Griliches (1967). The authors show that the rates of growth of total real output and total real input have to be calculated as weighted averages of the growth of all individual products and factors. On this condition, and if the production function has constant returns to scale and markets are competitive, changes in multi-factor productivity are accurately described by shifts in the production function. This means that, on the real factor input side, attention must be paid to the correct measurement of services that flow from the stock of labour and capital and form inputs into the production function. In particular, the heterogeneity of these inputs must be kept in mind and correctly accounted for. Whenever the composition of these inputs varies, be it from the point of view of quality, age or some other characteristic, this change also adds or subtracts from the contribution of the factor. The measurement of capital input from this point of view is discussed by Griliches and Jorgenson (1966) and OECD (2001a). Jorgenson et al. (1987) and Schwerdt and Turunen (2006), among others, analyse the measurement of labour input. A recent discussion of the implications of some standard production function assumptions for the measurement of multi-factor productivity is provided by Schreyer (forthcoming). The current paper focuses on the measurement of the contribution of capital to economic output growth in the Czech Republic.

The stock of capital, while being an appropriate measure of wealth, does not capture correctly the contribution of existing capital to aggregate production. OECD (2001a) identifies three main problems with using the measured net capital stock as an input in estimating production functions. The first problem is that unlike other (supposedly correctly measured) variables in the production function, which enter as flows, this capital measure enters the production function as a stock and therefore imposes inconsistency in dimensions. The second drawback to using the capital stock is that it does not adequately account for the heterogeneity of capital assets. Conventional measures of the gross or net capital stock do not fully reflect the productive efficiency of capital assets. Hence, if the gross capital stock is used, all capital assets are regarded as new, providing continuously the same quality of service, until their assumed retirement. A net capital measure accounts to a certain extent for the loss of productive capacity during the service life, but if it is evaluated at market prices, the measure will most probably underestimate productive efficiency in the early years of the service life, when prices typically decline quite rapidly. And thirdly, when aggregating across assets to obtain the total value of the (gross or net) capital stock, each asset is weighted by its market value. This basically implies that by using the growth rate of this measure to capture the growth of productive capital input, two assets with the same value will have the same weight in accounting for their contribution to production in a given year. Thus, expensive assets with a long service life are assumed to make a relatively larger contribution to annual production than cheaper assets with short lives.

When assessing the contribution of capital to production, therefore, it is necessary to pay attention to changes in the flow of services that derive from changes in the capital asset structure. Dynamic development in the stock of highly productive assets, such as information and communication technology assets, may not result in noteworthy changes to the measured stock of capital. This is because such assets usually have a short service life and therefore a relatively lower price; consequently, they have a lower weight in the total capital stock compared to assets with a long service life. If the asset structure develops towards more productive assets (i.e. assets with higher marginal productivity and, hence, rental cost), using the capital stock as a measure of capital input into production may underestimate the true productive contribution of capital. The measure of capital services will, on the other hand, capture it, since it looks precisely at the quantity and value of the flow of productive capital services deriving from capital assets, i.e. the contribution of capital to production.

Notwithstanding its importance to correctly accounting for productive capital input, measuring capital services is not straightforward. Capital is frequently owned by its user, meaning that the flow of capital services is not intermediated by the market and the full set of quantities and prices of capital inputs is not observed. This is why in many countries, including the Czech Republic, a measure of capital services is not readily available. Exceptions include the United States, Canada and Australia, where such measures are published officially. Experimental measures exist for the United Kingdom and New Zealand. The OECD produces capital measures for nineteen OECD countries.[1]

The measure of capital services has, however, been preferably applied in analyses of aggregate and sectoral productivity and of potential output. Vijselaar and Albers (2002), for instance, analyse the effect of new technologies on productivity growth in the euro area, while Oulton and Srinivasan (2005) do the same for the United Kingdom. Inklaar et al. (2003) analyse the effects of development and use of information and communication technology for the difference between EU and US productivity growth. Beffy et al. (2006) estimate potential output in selected OECD countries using the measure of capital services.[2]

So far, the measure of capital input into the production function used in studies concentrating on the Czech economy has mostly been the stock of capital as provided by the Czech Statistical Office[3] or as calculated based on data from the Czech Statistical Office[4]. The notion of capital services was, in contrast, used by Piatkowski (2003) in a study of eight Central and Eastern European countries in which the author calculates the contributions of ICT and non-ICT capital services to economic growth in 1992–2000 using data on ICT spending from a private source (International Data Corporation).[5] Dybczak et al. (2006) use the measure of capital services described in this paper to disentangle Czech economic growth at the aggregate level.

The current paper describes an experimental measure of capital services for the Czech Republic. An earlier version of this measure with underlying data of an older vintage was used in Dybczak et al. (2006). The methodology described in Schreyer et al. (2003) is followed, though it is simplified to accommodate the data. Further, the contribution of capital based on the presented experimental measure of capital services is compared with that based on the measure of the

[1] Capital measures for eight OECD countries are presented in Schreyer (2003). Beffy et al. (2006) use capital services measures for nineteen countries.

[2] Application to supply-side analysis need not be the sole use of the measure of capital services. For instance, a correctly estimated measure of total factor productivity would be useful for an analysis of price-level convergence.

[3] For example in Hurník and Navrátil (2005).

[4] For example in Hájek (2008).

[5] There are, however, several drawbacks to the measure used in Piatkowski (2003). Due to a lack of data, assumptions are required about the ratio of investment to spending for information technology, communications technology and software, and on ICT investment before 1992.

capital stock and an inference is drawn about changes in the productive capacity of capital. A higher contribution based on the experimental measure of capital services signals positive changes of capital productivity in the Czech Republic. The impacts on measured multi-factor productivity are shown in a simple growth accounting exercise. Constructing the measure of capital services also permits use of an exogenous rate of return to capital in such an exercise.

2. Capital Services: Method and Data

2.1 Capital Services

The contribution of capital to production naturally derives from the existing stock of capital. The market value of this stock of capital is not, however, a correct measure of the contribution. Partly analogous to the contribution of labour, which can be measured as hours worked in the economy, the capital input of machinery, for instance, would ideally be measured as machine hours and the machine hours distinguished according to the value of the service of particular machinery assets.[6] The concept of capital services captures the flow of services from a capital asset that forms a contribution to production. In general, the marginal productivity of different assets (machinery, transport equipment, software, etc.) in production is not the same, and this should be reflected in the weighting scheme that is applied to aggregate the services of different types of assets. Such a weighting scheme should be based on user cost, not on purchase prices, and should be updated regularly by using a chain-weighted index number formula.

The notion of capital services as a concept different from the net capital stock was first described by Griliches and Jorgenson (1966). In contrast to labour input, which is relatively easily measurable,[7] measuring the services of capital is more difficult. The most important problem is that most transactions which entail the use of capital services do not appear on the market, since capital is frequently owned by its user, and the price and quantity of capital services used for production are therefore not observed. An inference must therefore be drawn from the development of the productive stock of particular assets and be combined with information about the user cost of these assets, which, in theory, should reflect the value of the capital services these assets can provide.

The OECD *Manual on Capital Measurement* (OECD, 2001a) and Schreyer et al. (2003) provide a framework for measuring capital services. Capital services are viewed as a flow of productive services from the cumulative stock of past investments. The quantity of productive services $K^i_{t,s}$ in year *t* of a capital asset of type *i* and age *s* years is proportional to the volume of investment in this asset *s+1* years ago, I^i_{t-s-1}, expressed in constant prices,

$$K^i_{t,s} = \lambda^i_t F^i_s I^i_{t-s-1} \tag{1}$$

[6] The analogy with labour input is not exact, since, due to unobservability, the quantity of capital services does not often capture capacity utilization, the cyclical variation being captured rather well by the measure of hours worked. On the other hand, a measure of hours worked does not capture the heterogeneity of the factor input, while the measure of capital services is designed to do so.

[7] Some studies choose to account for heterogeneity of labour while some studies choose to ignore it. The heterogeneity of labour input is taken into account in, for example, OECD (2003).

where λ_t^i is a proportionality factor that links the flow of capital services to a vintage investment and F_s^i reflects the retirement pattern of asset *i*. F_s^i represents a distribution around the expected service life of this asset; it is non-negative, falling in *s* and takes the value of 1 for a new asset (i.e. if $s = 0$).

The price of using a capital service $K_{t,s}^i$ is $uk_{t,s}^i$ and the value of the services at time *t* derived from asset *i* acquired *s* years ago is equal to $uk_{t,s}^i K_{t,s}^i$. The value of capital services of asset *i* used at time *t* can be expressed as follows:

$$uk_t^i K_t^i = \sum_{s=0}^{t-1} uk_{t,s}^i K_{t,s}^i \quad (2)$$

where $uk_{t,s}^i K_{t,s}^i = uk_{t,s}^i \lambda_t^i F_s^i I_{t-s-1}^i$. The price of using a capital service in principle differs from the price of using a unit of capital good (the user cost). The cost of using one unit of vintage investment, $u_{t,s}^i$, is proportional to the price of the capital service:

$$u_{t,s}^i = \lambda_t^i uk_{t,s}^i \quad (3)$$

The productive stock S_{t-1}^i of asset type *i* at the end of period *t-1* can be computed by the perpetual inventory method as the sum of all vintage investment (*s* years ago) in this type of asset, I_{t-s-1}^i, expressed in base year prices, corrected for the probability of retirement and for the loss of productive capacity,

$$S_{t-1}^i = \sum_{s=0}^{t-1} h_s^i F_s^i I_{t-s-1}^i \quad (4)$$

where h_s, the age-efficiency function, describes the loss of productive capacity of a capital good because of “wear and tear” and technical obsolescence.[8] It is a non-negative function which declines in *s* with h_s=1 for a new capital good and h_s=0 for a capital good that has reached its maximum service life. In a functioning market, the following relationship holds: $h_s^i / h_o^i = u_{t,s}^i / u_{t,0}^i$. Combining (4) with (1), (2) and (3), one obtains:

$$uk_t^i K_t^i = u_{t,0}^i \sum_{s=0}^{t-1} h_s^i F_s^i I_{t-s-1}^i = u_{t,0}^i S_{t-1}^i \quad (5)$$

i.e. the value of capital services from i-type assets is equal to the product of the productive stock of these assets (expressed in “new equivalent” units) and its user cost. This identity can be used in quantifying the flow of capital services. The change in the volume of capital services flowing from asset *i* is then measured by the index of the productive stock S_t^i / S_{t-1}^i.[9]

[8] A cost-minimizing producer will equalize the relative productivity of assets of different age with their relative user cost. The presented functional form also relies on the assumption that capital goods of the same type are perfectly substitutable.

[9] The argument is based on the assumption that the correct deflator for the value of capital services is the user cost of a new asset. An alternative is to deflate the value of capital services by the user cost per unit of capital

In order to construct the aggregate measure, it is necessary to keep in mind that each type of asset produces a specific flow of capital services in proportion to its productive stock. This proportion, however, differs across assets. The weights for aggregations thus must reflect the marginal productivity of different assets. Market prices of capital assets are not suitable weights because they reflect the flow of capital services of the assets over their expected remaining service life but not for a single year. In contrast, the user cost, in equilibrium, equals the marginal revenue of an asset and hence is the correct weight.

The user cost of an *s*-year-old asset *i* at time *t* with the information set of *t-1* is defined as follows:[10]

$$u_{t,s}^{i}\big|\Omega_{t-1} = q_{t-1,s}^{i}\left(r + d_{t,s}^{i} - \zeta_{t}^{i} + d_{t,s}^{i}\zeta_{t}^{i}\right) \tag{6}$$

where $q_{t-1,s}^{i}$ is the purchase price of the asset, r is the nominal discount rate, $d_{t,s}^{i}$ is the depreciation rate and ζ_{t}^{i} is the rate of asset price change.[11]

The change in the volume of capital services is then given by

$$\ln\frac{K_t}{K_{t-1}} = \ln\frac{S_{t-1}}{S_{t-2}} = \sum_i \frac{1}{2}\left(\frac{u_{t,0}^{i}S_{t-1}^{i}}{u_{t,0}S_{t-1}} + \frac{u_{t-1,0}^{i}S_{t-2}^{i}}{u_{t-1,0}S_{t-2}}\right)\ln\frac{S_{t-1}^{i}}{S_{t-2}^{i}} \tag{7}$$

Below, *i* is identified with either the class of assets distinguished by their “type” (i.e. falling into these groups: dwellings, other buildings and structures, transport equipment, other machinery and equipment, cultivated assets, computer software and other intangible fixed assets) or assets accumulated in a particular industry. The difference between these methods will consist in how well one is able to measure the different characteristics of the particular asset groups. The theoretically better approach is to use the breakdown by asset, since the different elements of the user cost of capital (depreciation, price change) for a type of asset as constructed according to (6) will be more robust than for an industry. The reasons are that the particular assets in the “asset-type” group are more homogeneous and thus the average depreciation rate and average expected price changes will correspond better to the characteristics of particular assets relative to the “industry” group of capital assets. On the other hand, the precision of the method grows with the degree of disaggregation, and, as will be described below, more detailed data are available for a breakdown by industries. Calculation of the experimental measure of capital services was, therefore, conducted for both these approaches. This provides us with the opportunity to compare the measures and also, to some extent, to assess their robustness.[12]

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services. The two options do not have different growth implications if λ^i is time invariant. If there is, however, time variation in this parameter, e.g. cyclical fluctuations in the capacity utilization, the current measure does not fully capture the variation in capital services.

[10] As derived by Schreyer et al. (2003).

[11] This definition of user cost ignores the cost of adjustment, which can lead to a slower reaction of investment to changes in the cost of financing. However, the real ex-post cost of finance used in this analysis does not impose any cycle-related behaviour of the capital service series.

[12] Ideally, one could combine the two approaches and use the breakdown by asset *and* industry, which would profit from the maximum available information. Unfortunately, this could not be pursued because of a lack of some necessary data in this breakdown.

The shortcoming of the measure of capital input into production presented above is that it assumes a proportional flow of capital services from the existing capital stock, i.e. a full (or steady) utilization of the capital stock. It does not pay attention to the variation in the rate of capacity utilization that naturally occurs during the production cycle, or, for instance, because of seasonal or trend changes in demand, breakdown of equipment, etc. The described measure thus in fact represents a measure of the potential flow of capital services and hence the potential contribution of capital to production. This may be an advantage when a measure of potential output is being constructed. One has to keep this feature in mind, however, when using the measure of capital services for productivity measurement. The measure of capital services has a tendency to overestimate the capital contribution to production in downturns. A measure of multi-factor productivity based on this measure of capital services contains this effect.[13]

2.2 Available Data

The national accounts[14] data on the net stock of fixed capital, consumption of fixed capital, and changes in the valuation of fixed assets were obtained from the Czech Statistical Office.[15] The flow data are expressed in current and constant prices, and the net stock data are expressed in current and constant replacement cost.[16] In a breakdown by industry and type of asset, consistent time series in an annual frequency are available for the measures of gross fixed capital formation, capital consumption at current and constant prices and net capital stock at current and constant replacement cost. These time series are available in a breakdown for 58 groups of industries (based on the NACE classification) and for seven types of assets[17] for the period 1995–2007.

In general, the length of publicly available investment time series is insufficient to allow for the application of equation (4) to compute the series of the productive stock of capital.[18] In this paper it is assumed that at the level of individual classes of assets the net stock of a capital asset at replacement cost (as computed by the Czech Statistical Office) correctly accounts for most of the age and obsolescence effects and thus the loss of productive capacity of these assets. One could thus assume that the productive stock of a particular capital asset, S_{t-1}^{i}, as defined in (4), can be well described by the measure of the net stock of capital at constant replacement cost, where i would stand either for a type of capital asset or for an industry.

Equation (4) requires the accumulated investment in one type of asset to be corrected for the probability of retirement and for the loss of productive capacity by wear and tear and technical obsolescence. This is also what the perpetual inventory method in theory does: the net capital stock is compiled as the gross capital stock (i.e. the sum of past investment) minus accumulated

[13] However, this characteristic is not a drawback vis-à-vis the measure based on the capital stock.

[14] ESA 1995 methodology.

[15] Annual national accounts, time-series of non-financial assets, http://dw.czso.cz/pls/rocenka/rocenkavyber.nfa_t

[16] Definitions of current and constant replacement cost by Eurostat (1997, http://forum.europa.eu.int/irc/dsis/coded/info/data/coded/en/gl008781.htm).

[17] Tangible fixed assets: dwellings, other buildings and structures, transport equipment, other machinery and equipment, cultivated assets, intangible fixed assets: computer software, other intangible fixed assets.

[18] A detailed description of the Perpetual Inventory Method, including data requirements, is given, for example, by Meinen et al. (1998).

consumption of fixed capital (i.e. the "amount of fixed assets used up, during the period under consideration, as a result of normal wear and tear and foreseeable obsolescence"[19]).

The Czech Statistical Office uses the perpetual inventory method for calculating the stock and consumption of fixed capital of all types of assets except for dwellings and some selected types of building structures, for which a quantitative method based on information about quantity and unit prices is used. The bell-shaped (lognormal) retirement pattern is used for machinery and equipment and software.[20] Also, the lengths of asset service lives used by the Czech Statistical Office are (along with those used in the United States, Canada and the Netherlands) considered by the OECD to "*appear to be based on information that is generally more reliable than is usually available in other countries*" (OECD, 2001a, p. 104). It is therefore acceptable to assume that the net stock of a particular fixed asset (except for dwellings and non-residential building structures) is a fairly accurate approximation of the productive stock of capital for the asset classes considered.

The productive stock of capital S_{t-1}^{i} is hence approximated by the corresponding measure of the net stock of capital at constant replacement cost in the corresponding asset/industry segmentation from the Czech Statistical Office.

2.3 User Cost Calculation

The weights for the aggregation (the user costs) are constructed as defined in (6). To establish the required nominal rate of return at time t (the opportunity cost of financial capital invested in an asset), I take into account the financing structure of firms and the effects of taxation. The expected real rate of net return to owners of capital reflects the real cost of equity and the real cost of debt. The cost of financing equity is calculated as the sum of the risk-free rate, proxied by the yield of a 10-year interest rate swap, and an equity premium of 6%.[21] As a proxy for the cost of debt, I use the average interest rate on the stock of bank loans to corporations, adjusted for the tax shield.[22] Both components are deflated by CPI inflation and their respective weights are 0.6 and 0.4, which approximates the prevailing financial structure of Czech corporations.[23] Since the real rate of return is rather volatile, but shows a certain trend, values smoothed by the Hodrick-Prescott filter are used to account for the relevant expectations. The required nominal rate of return is then obtained by adding an expected inflation component (a three-year centred average of observed inflation).

To account for the expected depreciation rate in the user cost, constant depreciation rates d_j for each asset type are computed as averages of the realized depreciation rates.[24] The depreciation rate

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[19] Eurostat (2005).

[20] Sixta (2004). OECD (2001a) considers the lognormal mortality pattern as a realistic account of the retirement pattern.

[21] 6% is the historical average based on U.S. data. The current size of the equity premium in the Czech Republic might be higher than in the U.S. because, for example, of greater risk or lower liquidity. A sensitivity analysis is presented in Section 3.3.

[22] The source of data on the IRS and interest rates on credit is the Czech National Bank.

[23] The share is based on data from corporate surveys of firms with 100+ employees.

[24] In the industry breakdown the average is taken for the entire period. For certain asset groups the depreciation rates were somewhat volatile in the 1995–2000 period, while they stabilized in the period 2001–2007. The average for the latter period is therefore used.

of each asset type in each year is computed as the ratio of the consumption of fixed capital and the average net stock of fixed capital in the respective year, both at constant prices.

The purchase prices of the assets ($q^{i}_{t-1,s}$) are implicitly contained in the measure of the net capital stock at current replacement cost. The expected price change of capital is computed as a three-year centred average of the change in the deflator of gross fixed capital formation.

The capital income in each industry and for each type of asset is then computed as the product of the net stock of fixed assets at current replacement cost and the required gross rate of return (the expression in the parentheses in (6)). The share of each industry (asset) in total capital income then represents the weight that is assigned to the growth in the net stock of fixed assets at constant prices in this industry (asset). The sum of these contributions represents the growth of capital input (capital services) in a given year, as described in (7).

In contrast, the growth of capital input measured by net capital stock *W* where replacement cost weights *p* are used is computed according to (8):

$$\ln\frac{W_t}{W_{t-1}} = \sum_i \frac{p^i_{t-1}S^i_{t-1}}{p_{t-1}S_{t-1}} \ln\frac{S^i_t}{S^i_{t-1}} \qquad (8)$$

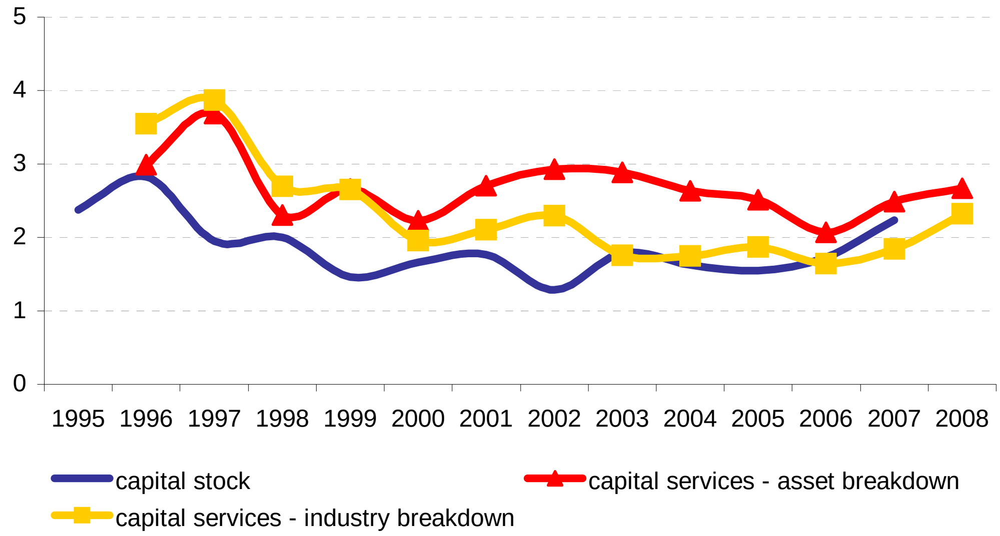
3. Capital Services: Results

The main difference of the capital services measure from the measure of the net capital stock consists in recognizing that different types of capital assets produce a flow of services with different price and quantity distributions over time. Paying attention to the structure of capital thus better captures the aggregate input into production.

Figure 1 compares the development of the measures of the net capital stock and capital services constructed based on the asset-type and industry decomposition of capital assets between 1996 and 2007. The time coverage of the two time series is shifted because according to the model employed, capital services derive from the previous-year productive stock. The measured growth rate of capital services based on asset decomposition is in all years higher than the growth rate of the net capital stock. This means that measuring the capital contribution to production by the net capital stock underestimates the productive capital input.

On the other hand, the measure of capital services based on the industry decomposition is higher than the capital stock-based measure in the period up to 2003. After that, the measures roughly converge. The next sections describe in more detail the different developments of the two capital services measures.

Figure 1: Capital Services and Net Capital Stock (yearly growth, %)



According to the results presented, growth of capital services as measured by the preferred asset-type measure was highest at the beginning of the period analysed, with a peak of 3.7% in 1997 and a decline afterwards to 2–3%. This development reflects the investment boom of 1994–1996 (reflecting the first wave of foreign direct investment in the Czech Republic), but the rate of growth of capital services remained high despite a slump in economic activity in 1997 and 1998 and resultant decline in investment activity in the rest of the 1990s. Hanzlová (2001) analyses investment activity in the Czech Republic in the 1990s and finds that the investment activity of Czech companies in the second half of the 1990s consisted chiefly in infrastructure and restructuring investment, the infrastructure investment being crucial for the cultivation of the entrepreneurial environment but not having an immediate impact on the production capacity of the economy. Investment in machinery and equipment concentrated mostly on the industries of interest to foreign investors, and, in general, the high average age of capital assets (a legacy of the previous economic regime) did not decrease considerably. According to the report, replacement of capital stock was most intensive in the energy sector, telecommunications and production of dual-track vehicles. More pronounced investment in the information and communication technology-producing sector emerged only in 2000 thanks to the investment activity of foreign-owned enterprises.[25]

Investment in information and communication technology in general was, on the other hand, probably dynamic already in the second half of the 1990s. According to Piatkowski (2003), ICT spending grew by rates above 5% at the beginning of the 1990s and further accelerated after 1996.[26] The author estimates that between 1995 and 2000, the share of the net ICT real capital stock in the total net capital stock increased from approximately 2% to 6%, which could account for about 0.7 percentage points of the output growth in the period on average. The Czech Statistical Office data on gross fixed capital formation by commodity show strong investment in radio, telephone and communications equipment (CPA group 32) and computer technology services (CPA group 72); the shares of these groups of commodities in total investment increased

[25] The development of technical infrastructure and information and communication technology diffusion between 1998 and 2004 in the Czech Republic is described by the Czech Statistical Office (2005).

[26] Expressed in USD. ICT spending includes investment as well as payments for services.

during 1995–2000 from below 1% to over 5% and from below 2% to over 3% respectively. The share of office machinery and computers, on the other hand, remained approximately constant.[27]

After 2000, the economic development in the Czech Republic showed a tendency towards increasing economic growth with a temporary deceleration in 2001–2002 and a gradual slowdown from high growth rates after 2006. Investment activity peaked in 2000–2002 and in 2006–2007. The asset-type based measure indicates that growth of capital services remained between 2 and 3% over the period after 2000, while the industry-based measure indicates somewhat lower growth of capital services.

3.1 Information in Asset Structure

Table 1 presents details of the capital input measures from the perspective of asset structure and compares the contributions of particular asset types to capital services growth (left pane) and net capital stock growth (right pane). It is apparent that the stock measure can underestimate the real growth of capital by more than one percentage point. Behind this difference lies mainly growth in transport equipment and other machinery and equipment assets, which are assigned more weight in the capital services measure. It can also be observed that while the contribution of computer software assets is negligible in the conventional measure, it is more significant in the new measure, where it contributes rather negatively until 2000 but then turns positive in the most recent period. This can be attributed primarily to increased investment in computer software, which was rather weak in 1997–1998 and was not sufficient to cover the depreciation of these assets. The subsequent pickup in investment then resulted in a positive contribution of computer software to capital services growth. The contribution of buildings, structures and dwellings, in contrast, is slightly downplayed by the measure of capital services.

The main factors behind the differences between the two measures are highlighted in Table 2. The first column reports the average depreciation rates, and the second and third columns compare the average weights of the asset groups in the measure. The average contributions in percentage points of asset groups to growth in the net capital stock and in capital services, respectively, appear in the fourth and fifth columns, and in the last column the percentage difference between growth and contributions is reported. The difference in the weights is quite remarkable: while dwellings and other buildings and structures, i.e. assets with long service lives and relatively less technology involved, represent more than 80% of the total in the value of capital, in the (estimated) yearly payments for capital services they only account for about 60%. The weights and, hence, contributions of transport equipment, other machinery and equipment and other intangible assets are more than twice as high when the user cost is used for aggregation than when the share in the value of the capital stock is used, and the contribution of computer software is approximately thirty times higher.

[27] The shares were calculated based on current prices data. The fast process of obsolescence of ICT assets implies fast decreases in prices, which probably means that data at current prices underestimate the dynamism of these assets.

Table 1: Growth Rate of Capital Input – contributions by types of assets, per cent and percentage points

	Capital services Yearly contribution by cost								Net capital stock Yearly contribution by value							
	Total	Dwellings	Other buildings and structures	Transport equipment	Other machinery and equipmen	Cultivated assets	Computer software	Other intangible fixed assets	**Total**	Dwellings	Other buildings and structures	Transport equipment	Other machinery and equipmen	Cultivated assets	Computer software	Other intangible fixed assets
1996									**2.9**	0.2	1.6	0.2	1.0	0.1	0.0	-0.1
1997	**3.7**	0.1	1.0	0.5	2.2	0.1	0.0	-0.2	**2.0**	0.2	1.0	0.1	0.7	0.0	0.0	-0.1
1998	**2.3**	0.1	0.7	0.2	1.7	0.1	-0.3	-0.2	**2.0**	0.2	0.9	0.2	0.8	0.0	0.0	-0.1
1999	**2.7**	0.1	0.7	0.5	1.6	0.0	-0.1	-0.2	**1.5**	0.2	0.6	0.2	0.6	0.0	0.0	-0.1
2000	**2.2**	0.1	0.4	0.4	1.3	0.0	0.3	-0.2	**1.7**	0.2	0.5	0.3	0.8	0.0	0.0	-0.1
2001	**2.7**	0.2	0.3	0.6	1.6	0.0	0.2	-0.2	**1.8**	0.2	0.5	0.4	0.6	0.0	0.0	0.0
2002	**2.9**	0.1	0.4	0.9	1.3	0.0	0.2	0.0	**1.3**	-0.2	0.2	0.5	0.7	0.0	0.0	0.0
2003	**2.9**	-0.1	0.2	1.1	1.5	0.0	0.2	0.0	**1.8**	0.2	0.7	0.4	0.4	0.0	0.0	0.0
2004	**2.6**	0.2	0.5	0.9	0.9	0.0	0.0	0.0	**1.6**	0.2	0.7	0.3	0.4	0.0	0.0	0.0
2005	**2.5**	0.1	0.5	0.8	0.9	0.0	0.2	0.0	**1.6**	0.2	0.8	0.3	0.2	0.0	0.0	0.0
2006	**2.1**	0.1	0.6	0.8	0.5	0.0	0.1	0.0	**1.7**	0.2	0.8	0.3	0.3	0.0	0.0	0.0
2007	**2.5**	0.2	0.6	0.8	0.7	0.0	0.2	0.0	**2.3**	0.4	1.2	0.4	0.3	0.0	0.0	0.0
2008	**2.7**	0.3	1.0	0.8	0.5	0.0	0.1	0.0								
Average 1997-2002	**2.8**	0.1	0.6	0.5	1.6	0.0	0.1	-0.2	**1.7**	0.1	0.6	0.3	0.7	0.0	0.0	0.0
Average 2003-2007	**2.5**	0.1	0.5	0.9	0.9	0.0	0.2	0.0	**1.8**	0.2	0.9	0.4	0.3	0.0	0.0	0.0

Table 2: Information in Asset Structure

	depreciation rate yearly average % 2001-2007	average weight (%) in value *(net cap.stock)* 1995-2007	average weight (%) in user cost *(cap.services)* 1996-2007	average contribution (p.p.) by value *(net cap.stock)* 1997-2007	average contribution (p.p.) by user cost *(cap.services)* 1997-2007	difference of contribution (p.p.)
Total	5.0	1.00	1.00	1.9	2.7	-0.8
Tangible fixed assets	4.7	0.99	0.97	1.9	2.7	-0.8
Dwellings	2.3	0.25	0.17	0.2	0.1	0.1
Other buildings and structures	2.9	0.57	0.42	0.9	0.6	0.3
Transport equipment	15.6	0.03	0.08	0.3	0.6	-0.3
Other machinery and equipment	13.2	0.14	0.30	0.5	1.4	-0.8
Cultivated assets	2.3	0.00	0.00	0.0	0.0	0.0
Intangible fixed assets	44.3	0.01	0.03	0.0	0.0	0.0
Computer software	55.3	0.00	0.02	0.0	0.1	-0.1
Other intangible fixed assets	28.2	0.00	0.01	0.0	-0.1	0.1

3.2 Information in Industry Structure

Table 3 shows how different the contributions of individual industries are if user costs are used as weights for the aggregation (left pane) or the shares in the total value of capital are used as weights (right pane). For clarity, results for individual industries are aggregated into eight main groups. The average difference for the total growth of productive capital input is again almost one percentage point, though somewhat lower than for the capital services measure based on the asset breakdown, especially in the period 2004–2007, when the difference almost vanishes.

From the point of view of industry composition, the main difference between the measures stems from the contributions of industry and transport. The highest relative increase of the contribution when user costs are used (observable also in Table 4) is for the transport industry. Within this contribution, there are significant positive and increased contributions in the sectors of post, telecommunications and land transport, but also a significant negative contribution from the sector of auxiliary operations in transport and travel agencies. The net capital stock of the latter industry is formed by the transport infrastructure, which accounts for around 10% of the total net capital stock. The contribution of capital assets in industry also covers the assets in mining and extracting industries and the energy-producing sector. The difference in the contributions of capital assets in the mining and extracting industries does not impose a large difference between the two measures of capital input. The contribution of capital in the energy-producing sector, however, creates almost 0.3 percentage point higher growth of capital input if measured by the growth in net capital. In manufacturing industries, the remarkable differences between the contributions weighted by user costs and share in value are mostly in favour of the measure of capital services. Contributing most to the difference is the manufacture of motor vehicles and trailers, machinery and equipment, fabricated metal products, rubber and plastic production, chemicals and paper production.

Table 3: Growth Rate of Capital Input – contributions by industry, per cent and percentage points

	Capital services Yearly contribution by cost									Net capital stock Yearly contribution by value								
	Agriculture and forestry	Industry	Construction	Trade, repair, hotels, rest	Transport	Financial intermediation	Real estate, rental, entrepreneurial activities	Other services	**Total**	Agriculture and forestry	Industry	Construction	Trade, repair, hotels, rest	Transport	Financial intermediation	Real estate, rental, entrepreneurial activities	Other services	**Total**
1996										0.2	1.2	0.1	0.4	0.3	0.2	0.3	0.1	**2.9**
1997	0.3	1.6	0.2	0.6	0.6	0.3	0.3	0.1	**3.9**	0.0	0.9	0.1	0.2	0.5	0.1	0.3	-0.2	**2.0**
1998	0.0	1.2	0.2	0.3	0.7	0.2	0.3	-0.2	**2.7**	0.0	0.8	0.1	0.3	0.4	0.0	0.5	-0.2	**2.0**
1999	0.0	1.1	0.2	0.4	0.6	0.1	0.4	-0.1	**2.7**	-0.1	0.7	0.0	0.4	0.2	0.0	0.3	-0.1	**1.5**
2000	-0.1	0.8	0.1	0.6	0.4	0.0	0.3	-0.1	**2.0**	0.0	0.6	0.1	0.2	0.4	0.0	0.5	0.0	**1.7**
2001	0.0	0.8	0.1	0.2	0.5	0.1	0.4	0.0	**2.1**	0.0	0.7	0.1	0.2	0.4	0.0	0.3	0.0	**1.8**
2002	0.0	1.0	0.2	0.2	0.5	0.0	0.2	0.1	**2.3**	0.0	0.7	0.1	0.2	-0.1	0.0	0.3	0.1	**1.3**
2003	0.0	0.9	0.1	0.2	0.0	0.1	0.3	0.2	**1.8**	0.0	0.5	0.1	0.2	0.2	0.0	0.4	0.3	**1.8**
2004	0.0	0.7	0.1	0.3	-0.1	0.0	0.3	0.3	**1.7**	0.0	0.6	0.1	0.2	0.2	0.0	0.5	0.1	**1.6**
2005	0.0	0.8	0.1	0.2	0.2	0.0	0.4	0.1	**1.9**	0.0	0.4	0.0	0.0	0.3	0.0	0.5	0.3	**1.6**
2006	0.0	0.5	0.0	0.1	0.3	0.0	0.4	0.3	**1.6**	0.0	0.2	0.0	0.2	0.5	0.0	0.7	0.1	**1.7**
2007	0.0	0.3	0.1	0.2	0.6	0.0	0.5	0.1	**1.8**	0.0	0.5	0.1	0.2	0.8	0.0	0.7	0.1	**2.3**
2008	0.0	0.6	0.1	0.3	0.7	0.0	0.6	0.1	**2.3**									
Average 1997-2007	**0.0**	**0.9**	**0.1**	**0.3**	**0.4**	**0.1**	**0.4**	**0.1**	**2.2**	**0.0**	**0.6**	**0.1**	**0.2**	**0.3**	**0.0**	**0.5**	**0.1**	**1.7**
Average 1997-2003	**0.0**	**1.1**	**0.1**	**0.4**	**0.5**	**0.1**	**0.3**	**0.0**	**2.5**	**0.0**	**0.7**	**0.1**	**0.2**	**0.3**	**0.0**	**0.4**	**0.0**	**1.7**
Average 2004-2007	**0.0**	**0.6**	**0.1**	**0.2**	**0.2**	**0.0**	**0.4**	**0.2**	**1.8**	**0.0**	**0.4**	**0.0**	**0.1**	**0.5**	**0.0**	**0.6**	**0.2**	**1.8**

Table 4 provides additional details to the above results. The measure of capital services allocates significantly more weight to changes in capital intensity in almost all industries to the detriment of, in particular, real estate activities and some other services, i.e. categories that would also have either a negative or negligible contribution if the net capital stock measure were used.

Table 4: Information in Industry Structure

	depreciation rate	average weight (%)		average contribution (p.p.)		difference
	yearly average	in value	in user cost	by value	by user cost	of contribution
	%	*(net cap.stock)*	*(cap.services)*	*(net cap.stock)*	*(cap.services)*	(p.p.)
	1995-2007	1995-2007	1996-2007	1997-2007	1997-2007	
Total	4.8	100.0	100.0	1.8	2.2	-0.4
Agriculture and forestry	7.2	2.1	3.0	0.0	0.0	0.0
Industry	6.5	22.2	28.1	0.8	1.2	-0.4
Construction	9.7	1.3	2.1	0.1	0.1	0.0
Trade, repair, hotels, rest	7.2	5.7	7.4	0.1	0.1	0.0
Transport	5.8	14.9	16.0	0.3	0.4	-0.1
Financial intermediation	9.9	1.4	2.1	0.4	0.3	0.1
Real estate, rental, entrepr.activities	2.8	29.0	20.8	0.0	0.0	-0.1
Other services	3.4	23.2	20.5	0.2	0.1	0.0

The convergence of the capital services measure based on the industry breakdown to the growth of the capital stock deserves some more attention. It can be observed that the convergence takes place especially after 2002. Table 5 looks more into the factors of this convergence. It can be observed that while there is minimal change in both the value and the cost structure between the periods 1997–2002 and 2003–2007, one can observe a difference especially in capital creation. The growth rate of the capital stock, which is also used as the proxy for the productive capital stock in the capital services computation, becomes more balanced across industries, which means that different weights translate into smaller differences in contributions. This is especially marked for industry, construction and transport, but is also significant for financial intermediation and trade.[28]

Table 5: Industry Breakdown – factors of convergence of measures

	1997-2002				2003-2007			
	average weight (%)		growth of		average weight (%)		growth of	
	in value	in user cost	net cap.stock	cap.services	in value	in user cost	net cap.stock	cap.services
Total	100	100	1.67	2.60	100	100	1.80	1.77
Agriculture and forestry	0.02	0.03	-0.47	0.92	0.02	0.03	-0.47	-0.51
Industry	0.22	0.28	3.28	3.87	0.23	0.28	2.02	2.38
Construction	0.01	0.02	7.50	7.68	0.02	0.02	3.62	3.89
Trade, repair, hotels, rest	0.06	0.07	4.04	5.08	0.06	0.08	2.73	2.71
Transport	0.15	0.16	1.99	3.55	0.15	0.16	2.51	1.23
Financial intermediation	0.01	0.02	3.10	4.83	0.01	0.02	0.10	0.73
Real estate, rental, entrepr.activities	0.29	0.21	1.25	1.47	0.29	0.21	1.93	1.91
Other services	0.23	0.20	-0.20	-0.17	0.22	0.20	0.84	1.01

3.3 Cost of Financing: Sensitivity Analysis

This section presents a simple sensitivity analysis vis-à-vis the assumption about the equity premium. The cost of financing, along with the expected physical depreciation and change in price, constitute the user cost used in the above analysis to approximate the marginal revenue from capital assets. The equity premium that co-determines the cost of financing is assumed to be 6% in the capital services index construction, which is the historical average based on U.S. data. However, for many reasons, such as risk or liquidity, the current size of the equity premium in the Czech Republic might be higher than in the U.S.

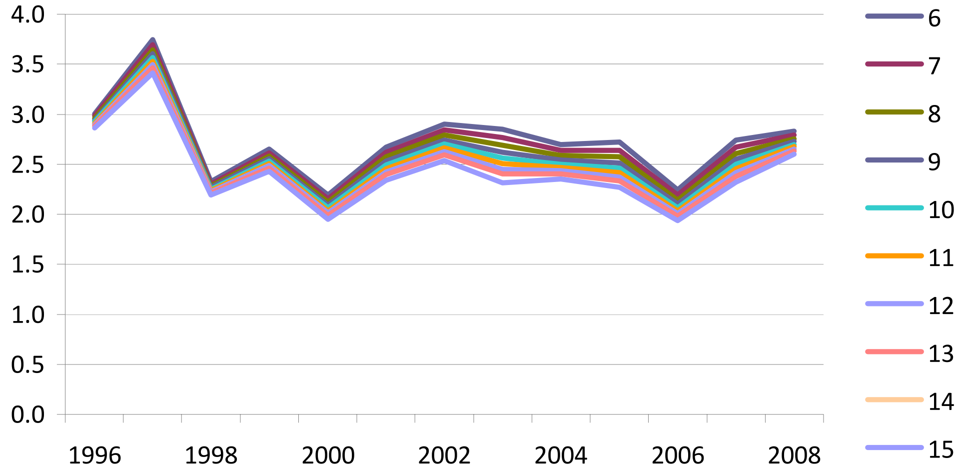
Since there is no common sense about the exact size of the equity premium in the Czech Republic, the sensitivity analysis looks at alternative possible values that are realistic for the Czech market. Since the Czech market is assumed to be still emerging, higher equity premium values than in the U.S. are explored. On the other hand, the country shows an already relatively high level of development, so excessive values for the premium do not have to be assumed. In the sensitivity analysis, a maximum of 15% is used, representing rather the upper end of the realistic assumptions.

Figures 2 and 3 show the results and draw the trajectories of capital services growth based on different equity premium assumptions. It can be seen that the capital service measures are not overly sensitive to the assumption regarding the equity premium. The larger is the equity premium and hence the cost of financing, the lower is the idiosyncratic part of the user cost that relates to the speed of loss in the value of those assets. By increasing the equity premium, hence, the heterogeneity among the assets in terms of the value of their capital service is reduced, which

[28] The standard deviation of the growth rates of the capital stock across the 58 industries decreased in 2003–2007 to less than half of the 1997–2002 value. A similar development occurred, albeit somewhat later, in the asset breakdown. This may be connected to the commencing economic boom.

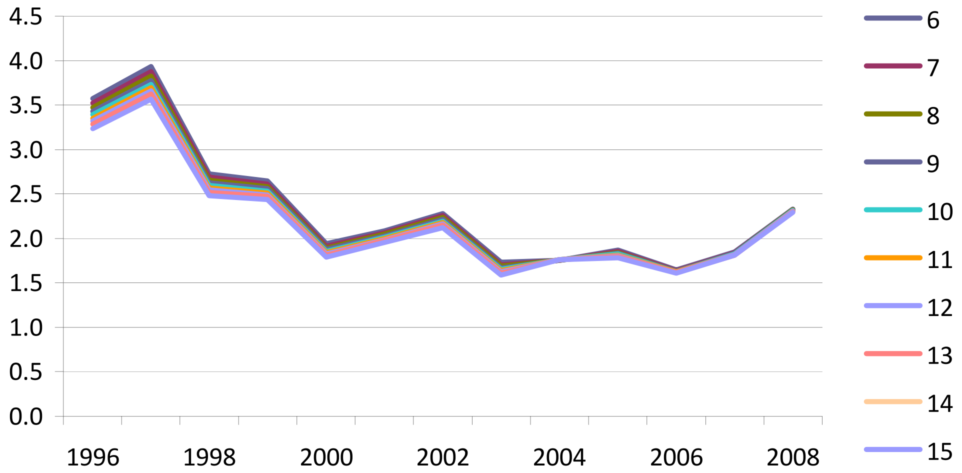
manifests in a slight downward shift of the estimated aggregate growth rates of capital services. In the industry breakdown, the difference fades away towards the end of the sample; this is connected with the above-described homogeneity of the growth rates in this period.

Figure 2: Equity Premium Assumptions and Capital Services Growth Estimates, per cent (asset breakdown)



Note: Capital services measures based on the asset decomposition as a result of different assumptions on the size of the equity premium (6% is assumed in the main analysis).

Figure 3: Equity Premium Assumptions and Capital Services Growth Estimate, per cent (industry breakdown)



Note: Capital services measures based on the asset decomposition as a result of different assumptions on the size of the equity premium (6% is assumed in the main analysis).

4. Accounting for Czech Economic Growth

Good measurement of capital input into production is important for the analysis of other developments in the economy. For instance, the correct measurement of multi-factor productivity allows for assessment of the effectiveness of investment. In times of dynamic development of information and communication technology, one should observe strong dynamics in MFP too, reflected in high labour productivity growth. In order to gauge the effect of the measurement of capital for MFP, I conduct a simple growth accounting exercise with a measure of capital based on stock and services measures. The difference in the underlying measure of capital input will be reflected in the ensuing measure of MFP.

Following Barro (1998), I carry out standard primal growth accounting using a neo-classical production function

$$Y = F(A, K, L) \tag{9}$$

where aggregate output Y is a function of capital input K, labour input L and multi-factor productivity A. Differentiation with respect to time and dividing by Y allows us to separate the growth rate of output into the sum of the contribution of factor inputs and technological progress:

$$\frac{\dot{Y}}{Y} = g + \frac{F_K K}{Y}\frac{\dot{K}}{K} + \frac{F_L L}{Y}\frac{\dot{L}}{L} \tag{10}$$

where $F_K = \frac{\partial F}{\partial K}$ and $F_L = \frac{\partial F}{\partial L}$ are the marginal products of capital and labour respectively, and $g = \frac{F_A A}{Y}\frac{\dot{A}}{A}$ is the growth to be ascribed to technological change. The latter is often also called the Solow residual, i.e. the part of economic growth that cannot be explained by the contributions of production inputs, and is interpreted as growth of multi-factor productivity (or the contribution thereof to economic growth).

If the price of capital service (uk) is equal to the social marginal product of capital, and the wage (w) is equal to that of labour, then $s_K = \frac{ukK}{Y}$ and $s_L = \frac{wL}{Y}$ are the respective shares of each factor remuneration in total product. In discrete time, the growth of output is then equal to the weighted sum of the growth rates of production inputs and MFP: [29]

$$\Delta \ln Y_t = g_t + s_{K,t}\Delta \ln K_t + s_{L,t}\Delta \ln L_t \tag{11}$$

Under the assumption of perfect competition in product and factor markets and constant returns to scale, the marginal products are reflected by rentals and wages. However, while labour remuneration is available from the national accounts, the remuneration of capital (i.e. the price and volume of capital services) is not directly observable. As described before, this is because the services of capital goods are often not sold or rented, as the capital used in production is very

[29] The approximation of the Divisia index for discrete time can be done, for example, by using a Törnqvist index.

often owned by the producer. Most of the transactions of renting capital services are hence not recorded and therefore not explicitly priced.

The share of capital remuneration in total output is thus very hard to obtain. However, the national accounts provide a quantity of gross operational surplus that complements remuneration of labour to total output at current prices. Some growth accounting exercises thus adopt the approach of computing the rate of return to capital endogenously by computing it as a share of gross operating surplus in total value added (or as a complement to one of the ratio of total wage cost to value added).

Nevertheless, this approach can be imprecise for at least two reasons. First, the gross operating surplus cannot be fully attributed to fixed capital. It is a measure of business profits from normal operating activity and includes so-called mixed income, i.e. income of self-employed persons and indirect business taxes. Secondly, in practice, the assumptions about constant returns to scale and competitive product markets need not hold. Relying on these assumptions may result in a bias in expressing the weights.[30]

Therefore, the logic of capital services is followed here for expressing the remuneration of capital and the concept of user cost of capital is used. In this sense, a measure of capital remuneration is created based on the total cost of capital, which is the product of the user cost of capital assets and the average net stock of these assets.

The weights of labour and capital respectively are then expressed by the following:

$$s_{L,t} = \frac{1}{2}\left(\frac{w_t L_t}{w_t L_t + uk_t K_t} + \frac{w_{t-1} L_{t-1}}{w_{t-1} L_{t-1} + uk_{t-1} K_{t-1}}\right), \text{ and}$$

$$s_{K,t} = \frac{1}{2}\left(\frac{uk_t K_t}{w_t L_t + uk_t K_t} + \frac{uk_{t-1} K_{t-1}}{w_{t-1} L_{t-1} + uk_{t-1} K_{t-1}}\right), \qquad (12)$$

where $w_t L_t$ is total remuneration of labour computed as the product of average compensation per employee and total employment (including self-employment to impute the dependent employment remuneration to the self-employed) in year *t* and $uk_t K_t$ is the total remuneration of capital computed as the sum over all industries of the product of user cost and the net capital stock in each industry in year *t*.

As pointed out by Jorgenson and Griliches (1967), the quantity indexes of total input and total output have to be constructed from the quantities of each output and each input, respectively, using the relative shares of the value of each output in total output and shares of each input in total input as weights. Therefore, when plugging the aggregate measures of total output and inputs into growth accounting, one has to be careful whether this principle was taken into account when constructing the aggregate measures.

[30] The issue is discussed by Wölfl and Hájková (2007). A detailed analysis of the consequences of different assumptions on the production function and markets for MFP measures can be found in Schreyer (forthcoming).

The measure of *Y* used in the following analysis is gross domestic product expressed in constant prices of 2000.[31] This measure is constructed by the chain-linking method and therefore conforms to the above recommendation that the weights of the growth rates of each individual output should be updated each period. Similarly, the measure of *K*, capital services, as described above, has been constructed to take into account this principle, too.

As regards labour, the standard measure of this input should reflect the variability in total employment as well as developments in average hours worked. In addition, one should consider changes in the structure of employment to take into account changes in the productive capacity of labour. This can be done, for instance, by dividing total employment with respect to gender and education, as was done, for example, by OECD (2003). The total labour input would then be defined as follows:

$$d\ln L_t = \sum_j \frac{1}{2}\left(s_{jt-1} + s_{jt}\right) d\ln h_{jt}\ , \tag{13}$$

where $s_{jt} = \dfrac{w_{jt}h_{jt}}{\sum_i w_{it}h_{it}}$, w_{jt} is the average wage for group *j* in year *t* and h_{jt} is the number of hours worked by group *j* in year *t*. The publicly available data do not allow a precise calculation of *d*ln*L* according to (14).[32] The composition effect is thus not accounted for in the measure of labour, which is then computed as the product of total employment and average hours worked[33] for each year. The measure of MFP thus contains the effect of improving productivity of labour stemming from the shift of its composition towards more productive (and higher paid) workers.

Table 6 depicts the effect of employing capital services measures (as constructed based on the industry and asset breakdown) in the growth accounting exercise for the Czech economy.[34] The results are in line with the finding above that the measure of capital based on capital services supports higher contributions of capital to production than the measure based on the net capital stock if the structure of capital changes towards more productive assets. It demonstrates the fact that the measure of capital services uses the correct set of weights that correspond to user cost and thus do not undervalue the contribution of short-lived capital assets. The measure of capital services also contains the effect of structural changes within the existing capital towards more or less productive use, which is also a contribution that should be recognized as related to capital and not to MFP in a growth accounting exercise. In our case, the calculated MFP hence should include

[31] The concept of OECD (2004 and 2001b) is followed by using GDP for the measurement of MFP at the aggregate level.

[32] Previous tentative computations suggest that for the Czech Republic in the period 1997–2004, the effect of structural changes in labour could be on average up to 0.5 percentage points to add to the growth of total labour input measured by the total number of hours worked in the economy. The size of the effect was computed based on (13) with eight groups of labour (broken down by gender and four education groups). It was assumed that the changes in average hours worked are identical across labour groups and that the wages of the group in education class ISCED 4 (post-secondary non-tertiary) are identical to the wages earned by workers with GCE (they are reported as higher; however, corresponding data on employment by education are not available).

[33] The measure of average hours worked was taken from OECD (2006).

[34] Cost shares are used for all free alternative capital measures for comparability.

minimum growth effects from capital.[35] But, as mentioned above, it can include a considerable contribution from the changes in the quality of labour input.

Table 6: Decomposition of Total Output Growth (growth in %, contributions in percentage points)

	GDP	employment	average hours worked	based on net capital stock		based on capital services (asset breakdown)		based on capital services (industry breakdown)	
				capital	MFP	capital	MFP	capital	MFP
1997	-0.7	0.1	0.1	0.8	-1.7	1.6	-2.6	1.7	-2.6
1998	-0.8	-0.8	0.2	0.9	-0.9	1.1	-1.1	1.2	-1.3
1999	1.3	-1.8	0.9	0.7	1.7	1.2	1.1	1.2	1.1
2000	3.6	-0.1	0.0	0.7	3.0	1.0	2.7	0.9	2.8
2001	2.4	0.2	-2.4	0.8	3.8	1.3	3.3	1.0	3.6
2002	1.9	0.3	-0.6	0.6	1.6	1.4	0.8	1.1	1.1
2003	3.5	-0.7	0.1	0.8	3.5	1.3	2.9	0.8	3.4
2004	4.4	0.2	0.2	0.7	3.3	1.1	2.9	0.7	3.2
2005	6.1	0.6	0.3	0.6	4.5	1.0	4.2	0.8	4.4
2006	6.6	0.9	-0.1	0.7	4.9	0.8	4.9	0.7	5.0
2007	6.4	1.0	-0.4	0.9	4.8	1.0	4.8	0.7	5.0
avg 1997-2007	3.2	0.0	-0.2	0.8	2.6	1.2	2.2	1.0	2.3

Using the experimental measure of capital services in the growth accounting exercise results in a rather significant reduction in the measured rate of growth of multi-factor productivity by 0.3–0.4 percentage points on average in the period 1997–2007. The difference diminishes towards the end of the covered period due to fading heterogeneity of the productive capital stock growth rates towards the end of the sample. This result, that using the measure of capital services leads to a reduction in MFP in a period of dynamic development of shorter-lived capital assets, is roughly in line with other findings in the literature. Schreyer (2003), for instance, who compares the MFP measures based on the net capital stock and net capital services for Australia, France and the United States, finds a similar reduction in MFP when the capital services measure is used to account for capital input.[36]

The description of the Czech business cycle from the supply-side point of view therefore differs from other descriptions available in the literature (e.g., Hájek, 2008) in the use of the respective weights of capital and labour in the growth accounting and in the division of the productive contribution between capital and multi-factor productivity. According to the results, capital contributed more to economic growth than the alternative measures in the literature would suggest. This is because the share of labour compensation in the factor costs is somewhat lower on average than its share in gross value added and the estimated growth rates of capital services are higher than those based on the net capital stock.

[35] The difference between the contribution of capital services and the contribution of the net capital stock, however, cannot be assumed to be a measure of the contribution of the quality of the net capital stock, since the measure of the capital stock uses incorrect weights for growth accounting.

[36] For the period 1995–2001, the difference ranges from 0.3 to 0.6 percentage points.

5. Conclusion

This paper constructs an experimental measure of capital services which should in theory better account for productive capital input than a simple measure of the net capital stock. It is shown that there is additional information in the standard published data on capital that can be used for this purpose. The experimental measure of capital services is based on the assumption that the officially published data on the net stock of capital assets at replacement cost reflect well the productive capacity of the existing capital. In order to calculate the growth of capital services in each year, the growth rate of the productive stock of each group of capital assets is assigned a weight that reflects the user cost of those assets, i.e. rentals. Two versions of a measure of capital services have been computed, one based on a breakdown by type of asset and the other based on a breakdown by industry. While the measure based on the asset breakdown is theoretically preferred, both measures indicate that the standard measure of the net capital stock, when used as an input into the production function, can underestimate the contribution of capital input to production when fast growth of highly productive (and usually short-lived) capital assets occurs, which can result in overestimation of multi-factor productivity in a growth accounting exercise.

In the case of the Czech Republic in the recent history covered by detailed and publicly available statistical data, the difference between the capital services and capital stock measures of productive capital input has been most important for the period up to 2005.

The measure still remains imprecise in several respects. Some limitations come from the method; the most important is that the suggested measure reflects the potential contribution of existing capital to production more than the actual one. Other limitations are caused by the use of the underlying data; in particular, the measure would be much more precise if a vintage effect could be added to the constructed measure. Also, the quality of the measure would clearly increase if the contribution of information and communication technology assets could be accounted for separately. For the time being, however, the experimental measure of capital services is a clear improvement over the measure of the net capital stock if the contribution of capital to production is to be described.

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Appendix: Additional Details of Calculation

Table A.1: The Eight Groups in which the Industry Breakdown is Presented (NACE classification)

	Sectors	Subsectors
Agriculture and forestry	A+B	01-05
Industry	C+D+E	10-41
Construction	F	45
Trade, repair, hotels, restaurants	G+H	50-55
Transport	I	60-64
Financial intermediation	J	65-67
Real estate, rental, entrepreneurial activities	K	70-74
Other services	L+M+N+O+P+Q	75-93
Total	A-Q	01-93

Table A.2: Growth Rates of Measures of Capital Input (% year on year)

	capital stock	capital services	
		asset breakdown	industry breakdown
1996	2.8		
1997	2.0	3.7	3.9
1998	2.0	2.3	2.7
1999	1.5	2.7	2.7
2000	1.7	2.2	2.0
2001	1.8	2.7	2.1
2002	1.3	2.9	2.3
2003	1.8	2.9	1.8
2004	1.6	2.6	1.7
2005	1.5	2.5	1.9
2006	1.7	2.1	1.6
2007	2.2	2.5	1.8
2008		2.7	2.3

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