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Abstract

This paper presents estimates of the aggregate net (wealth) capital stock and aggregate capital services for Switzerland. We derive these estimates in a consistent manner using the perpetual inventory method. Due to changes in data availability, the time series cover the period 1970-2005 for a 2-asset breakdown (equipment and structures) and 1990-2005 for a 12-asset breakdown (nine categories of equipment and three of structures). The sensitivity of the results is examined by varying assumptions on the initial capital stocks, the length of asset lives, the method for calculating service prices, and the choice of ICT deflators. Differences to the estimates published recently by the Federal Statistical Office are summarised in the appendix.

JEL Classification: C43, D24, D92, E22

Key words: capital stock, capital services, ICT goods

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1 Introduction

Measures of capital are used for many different purposes and the appropriate definition may differ, depending on the issue in question. In a wealth context, the *capital stock* is the stock of physical assets existing at a point of time. From a production perspective, however, *capital services* is the flow of services generated by these assets during a given period. Capital stocks and capital services denote two different but interrelated concepts of capital. On the one hand, capital services are derived from the stock of capital installed. On the other hand, the value of the capital stock reflects the discounted flow of future capital services.

The theory underlying the measurement of capital services was developed by Dale Jorgenson and co-authors in the 1960s. Jorgenson (1963) and Hall and Jorgenson (1967) showed how service prices, also called the user cost of capital, can be derived, even though they can not be observed directly. Jorgenson and Griliches (1967) and Jorgenson and Christensen (1969) developed the application of user cost of capital to the calculation of measures of capital input. Since then, the literature has grown rapidly. Jorgenson (1989), Hulten (1990) and Diewert and Schreyer (2006) provide excellent introductions. Practical guidelines for estimation can be found in two manuals published by the Organization for Economic Co-operation and Development (see OECD (2001a) and OECD (2001b)) and in Schreyer et al. (2005).

So long as the aggregate capital stock consists of a single type of capital goods, the capital stock and the flow of capital services will grow at the same rate over time. This follows from the conventional assumption that the capital services provided during a given period are proportional to the stock at the end of the previous period. Differences between the two measures of capital become more interesting when capital goods are heterogenous (as in reality they are). Information and communication technology (ICT) goods, for example, have shorter asset lives than buildings, and the relative price of ICT goods has fallen substantially over time. Under these circumstances, growth rates of the aggregate capital stock will differ from those of the flow of aggregate capital services. The differences can be traced back to the asset price to service price ratios associated with the various types of capital goods.

To make full use of these possibilities, we need investment data that do justice to the heterogeneity of capital goods. For many years, the National Accounts for Switzerland offered little detail, as gross fixed investment was broken down into not more than two categories - equipment and structures. The situation has improved with the publication of the National Accounts according to the international standard SNA93 in December 2003 (ESVG95). For investment, the move from ESVG78 to ESVG95 brought the widening of the definition of gross equipment investment (inclusion of computer software, in particular) and the breakdown of the data into nine categories for equipment and three categories for structures. The annual series for these twelve categories are available for the period from 1990 onwards.

In this paper, we present a set of measures of capital services and the net (wealth) capital stock for the aggregate Swiss economy. The net capital stock represents accumulated gross investment less accumulated depreciation. To simplify terminology, capital stocks henceforth are always net capital stocks. The range of assets considered is restricted to fixed produced assets. That is, we do not consider inventories, land, and intangible assets such as patents and trade marks. For both capital services and the capital stock, results are provided based on two different breakdowns of investment data: the 2-asset case drawing upon data for structures and equipment, and the 12-asset case drawing upon data for three categories of structures and nine categories of equipment. Reflecting data availability, the results cover the periods 1970-2005 (2-asset case) and 1990-2005 (12-asset case). The decision to calculate capital services for the 2-asset case results from the need to have access to time series reaching back beyond 1990. Moreover, it allows us to assess the effect of the heterogeneity of capital goods, as captured by the more detailed data available for 1990-2005.

To explore the robustness of our measures of capital, we recalculate our results based on several sets of alternative assumptions. These assumptions concern the life span of the various types of assets, the starting values of the asset stocks, the method for calculating the user costs of capital, and the choice of price indices used to compute ICT investment volumes. In addition, quarterly measures of capital and estimates of capital services based on mid-year asset stocks are considered. The assessment of price indices focuses on ICT goods because of the rapid technological progress in this field, which makes the measurement of constant-quality prices a difficult issue. Hedonic price indices are often recommended as an alternative to the conventional matched-model methods of quality adjustment. However, no such indices are compiled by statistical offices in Switzerland. We therefore make use of the hedonic price indices for ICT goods developed by the Bureau of Economic Analysis of the US Department of Commerce to examine the sensitivity of the results.

In 2006, the Federal Statistical Office (FSO) published estimates of growth in multi-factor productivity over the period 1991-2004 for Switzerland (FSO (2006b)). These results are interesting for our purpose because they are based on estimates of growth in capital services. In preparing this paper, we have reviewed our earlier estimates of capital stocks and capital services in light of the FSO publication. In consequence, we have adopted the FSO assumptions on asset lives but continue to differ in other respects. Appendix C summarises the differences in method and data and compares the results.

The paper is organised as follows. Section 2 provides a brief outline of the theory underlying the measurement of capital stocks and capital services. This is followed in Section 3 by the description of the data used to construct the annual series. Section 4 presents the results for the 2-asset case in the period 1970-2005. Section 5 presents the results for the 12-asset case in the period 1990-2005. Section 6 examines the sensitivity of the results to alternative sets of assumptions. Section 7 contains concluding remarks.

Three appendices provide information on selected issues. Appendix A gives further detail on definitions and sources of the data used in the calculations. Appendix B provides the growth rates and the shares in profits and in wealth of the twelve types of assets considered in the period 1990-2005. Appendix C describes the differences between our calculations and those by the FSO.

2 The measurement of capital

This section outlines the methodology of capital measurement. First, the perpetual inventory method is introduced (2.1). Then, aggregate capital services (2.2) and the aggregate capital stock (2.3) are derived. A brief review of aggregate rates of depreciation concludes the section (2.4). For a more detailed derivation of the results, see Jorgenson (1989) and Oulton and Srinivasan (2003).

2.1 The perpetual inventory method

The perpetual inventory method provides an approach for deriving estimates of the capital stock from the flow of investments for a given type of asset. The method starts off from a time series of investment volumes, which is obtained by deflating current-price investments with the appropriate price deflator. The price deflator should be a constant-quality price index so that all investment volumes are expressed in efficiency units of the year to which the price index is referenced (see Diewert et al. (2005), p. 25). Next, weights reflecting the age-efficiency profile are attached to each vintage. The age-efficiency profile describes how the efficiency of an otherwise homogenous asset changes with age. Finally, the weighted investment vintages are added together to give the capital stock. The stock of capital thus is a weighted sum of past investments, with weights corresponding to the efficiency of each vintage relative to that of the latest vintage.

Several profiles of relative efficiencies have been discussed in the literature: geometric, straight-line, "one-hoss shay", etc. With the "one-hoss shay" efficiency pattern, no loss in efficiency occurs during the lifetime of the capital good; a typical example is the light bulb. With the geometric and straight-line efficiency patterns, the efficiency of the capital good declines continuously. The geometric profile assumes that the efficiency declines at a constant rate, whereas the straight-line profile assumes that the efficiency declines by equal amounts in each period.

Age-efficiency profiles may not be confused with age-price profiles, which describe how the price of a given type of asset declines with age (depreciation). Under general conditions, the two profiles are not identical. But they are related to one another because the price of an asset is the present value of the service flow generated by the asset over its lifetime. It can be shown that there is an age-price profile for each age-efficiency profile, and vice versa.

In this paper, we assume the geometric model, which implies that the efficiency declines at a constant rate. The geometric model has the very useful feature that the age-efficiency profile coincides with the age-price profile. This simplifies the analysis and is a key reason for the widespread use of the model. Moreover, there is empirical evidence supporting the assumption of a geometric age-efficiency profile (see Hulten and Wykoff (1996)).

The capital stock of asset type i at the end of period t, $A_{i,t}$, can now be written as

$$A_{i,t} = A_{i,0} + \sum_{\beta=0}^{N}(1-\delta_i)^{\beta} I_{i,t-\beta} \tag{2.1}$$

or

$$A_{i,t} = I_{i,t} + (1-\delta_i)A_{i,t-1}, \tag{2.2}$$

where $I_{i,t}$ denotes gross investment and δ_i is the rate of depreciation which equals the rate of decay when the geometric model is assumed.

2.2 Shares in profits and aggregate capital services

Moving from stocks to services, we assume that, for a given type of capital, capital services during period t are proportional to the underlying capital stock at the end of the previous period. Setting the proportionality factor equal to 1, this gives:

$$K_{i,t} = A_{i,t-1}. \tag{2.3}$$

Section 2.1 has focused on the aggregation across vintages of a given type of asset. If all assets were of the same type, we could leave it at that. However, capital assets are heterogenous and, consequently, there is the problem of aggregation of capital services across asset types.

To aggregate capital services across types of assets, one needs information on the price of capital services, also called the user cost of capital. This is the rental price that has to be paid for the use of the capital goods during a given period. Generally, user costs of capital cannot be observed because most capital goods are utilised by the owner. However, in a competitive equilibrium, user costs of capital are linked to asset prices and therefore can be derived indirectly. The basic idea is that the equilibrium value of the implicit user cost must cover the opportunity cost of an investment plus the loss in the asset value. Ignoring adjustment costs and uncertainty, the arbitrage condition can be written as

$$r_t P_{i,t-1,0} = U_{i,t,0} + P_{i,t,1} - P_{i,t-1,0}, \tag{2.4}$$

where $U_{i,t,0}$ is the user cost of a new (i.e. age 0) asset of type i payable at the end of the current period, r_t is the nominal interest rate, $P_{i,t-1,0}$ is the price of a new i-type asset at the end of the previous period, and $P_{i,t,1}$ is the price of an i-type asset of age 1 at the end of the current period.

From Equation (2.4), a convenient form of the user cost of capital can be derived by introducing depreciation and asset inflation. Depreciation is the reduction in the market price due to ageing. Assuming that the depreciation rate on a new asset, δ_i, does not vary over time, we have

$$P_{i,t,1} = (1 - \delta_i) P_{i,t,0}. \tag{2.5}$$

Asset inflation, in turn, is the change in market prices for new assets between the end of period $t-1$ and t:

$$P_{i,t,0} = (1 + q_{i,t}) P_{i,t-1,0}, \tag{2.6}$$

where $q_{i,t}$ is the rate of inflation for asset type i.

Substituting Equation (2.5) and Equation (2.6) into Equation (2.4), solving for the user cost of capital, and dropping the age subscripts gives

$$U_{i,t} = [r_t + \delta_i - q_{i,t} + \delta_i q_{i,t}] P_{i,t-1}, \tag{2.7}$$

where $P_{i,t-1} = P_{i,t-1,0}$ and $U_{i,t} = U_{i,t,0}$. This is the user cost of capital formula of which several variants exist in the literature.[1]

Calculation of $U_{i,t}$ requires information on prices for new assets, the depreciation rates and the rate of return. The prices for new assets are the investment price deflators. The depreciation rates correspond to the geometric rates that describe the age-efficiency patterns in Equation (2.2). And the rate of return, r_t, can be derived from the equilibrium condition equating the total value of capital services to total profits, Π_t. That is:

$$\Pi_t = \sum_{i=1}^{m} U_{i,t} K_{i,t} = \sum_{i=1}^{m} [r_t + \delta_i - q_{i,t} + \delta_i q_{i,t}] P_{i,t-1} K_{i,t}, \tag{2.8}$$

where Π_t is measured by data on property compensation.

With the information on the capital services and the user cost of capital for each type of capital asset, we can aggregate capital services across asset types. The aggregation is done by the well-known Törnqvist-translog index. This implies that the growth rate of the volume of capital services is a weighted average of the growth rates of the services yielded by each asset, where the weights are the shares in the total value of capital services (i.e. in total profits):

$$\ln(K_t/K_{t-1}) = \sum_{i=1}^{m} \bar{w}_{it} \ln(K_{i,t}/K_{i,t-1}), \tag{2.9}$$

where

$$\bar{w}_{i,t} = \frac{w_{i,t} + w_{i,t-1}}{2}, \qquad w_{i,t} = \frac{U_{i,t} K_{i,t}}{\sum_{i=1}^{m} U_{i,t} K_{i,t}}. \tag{2.10}$$

This completes our discussion of the theory underlying the measurement of capital services. The growth rates of the volume of capital services can be calculated based on Equation (2.2), Equation (2.3), Equation (2.7) and Equation (2.9). Given total profits in a specific year, $\Pi_t = \Sigma_{i=1}^{m} U_{i,t} K_{i,t}$, a series for capital services at chained prices of that year can be calculated.

2.3 Shares in wealth and the aggregate capital stock

The aggregate capital stock is based on the market value of capital assets and corresponds to the wealth concept of capital. Because the stock of each type of asset is defined in units of new assets (see Equation (2.1)), the appropriate price indices are the deflators for investment. In the presence of quality changes, these should be constant-quality price indices.

[1] See Diewert (2003) for various forms of the user cost of capital and for references to early contributions from Eugen Böhm-Bawerk, Léon Walras and others.

The procedure up to the aggregation over vintages for each type of asset – Equation (2.2) – is the same for the aggregate capital stock and for aggregate capital services. However, the aggregation differs in that the stocks are weighted by relative market prices to obtain the aggregate capital stock (whereas the services derived from the stocks are weighted by relative rental prices).

The growth rate of the aggregate capital stock can thus be written as a weighted average of the growth rates of the stocks of each asset, with weights corresponding to the shares in the value of total assets (i.e. in total wealth):

$$\ln(A_t/A_{t-1}) = \sum_{i=1}^{m} \bar{v}_{it} \ln(A_{i,t}/A_{i,t-1}), \tag{2.11}$$

where

$$\bar{v}_{i,t} = \frac{v_{i,t} + v_{i,t-1}}{2} \qquad\qquad v_{i,t} = \frac{P_{i,t}A_{i,t}}{\sum_{i=1}^{m} P_{i,t}A_{i,t}}. \tag{2.12}$$

Based on Equation (2.11) and the total value of the assets in a given year, $\Sigma_{i=1}^{m} P_{i,t}A_{i,t}$, a series for the capital stock at chained prices of that year can be calculated.

2.4 Aggregate depreciation

For many purposes, it is interesting to look at the aggregate rate of depreciation. With depreciation rates differing from one class of assets to another and the composition of the capital stock changing over time, the aggregate depreciation rate will change as well.

The aggregate real rate of depreciation can be calculated based on the aggregate capital accumulation equation

$$A_t = I_t + (1 - \delta_t^R)A_{t-1}, \tag{2.13}$$

where I_t is aggregate real investment. Solving Equation (2.13) for δ_t^R gives

$$\delta_t^R = \frac{I_t - (A_t - A_{t-1})}{A_{t-1}}. \tag{2.14}$$

As Oulton and Srinivasan (2003) pointed out, δ_t^R may be unbounded and therefore must be interpreted with care. To avoid this problem, we can calculate

$$\delta_t^N = \frac{\sum_{i=1}^{m} \delta_i P_{i,t}A_{i,t-1}}{\sum_{i=1}^{m} P_{i,t}A_{i,t-1}}, \tag{2.15}$$

where δ_t^N is the aggregate nominal rate of depreciation.

3 Data

This section describes the annual data used to construct the aggregate measures of capital. To examine the effect of alternative assumptions on the results, some additional data will be necessary; these data will be described as the alternatives come up in the text (see Section 6). Appendix A provides information on data sources.

As described in Section 2.1, the first step in constructing aggregate measures of capital is to calculate the stocks of the various types of physical assets, A_i. This requires volume data on gross capital formation (gross investment), capital consumption (depreciation), and the initial stock of capital for each type of asset:

- The volume data for gross investment, $I_{i,t}$, are taken from the National Accounts. Data for investment in structures and equipment, respectively, are available for the period 1948-2006. Data for three components of structures and nine components of equipment are available for 1990-2005. All volume data are rebased on 1990 prices.

- The depreciation rates, δ_i, are assumed to be geometric and constant. With a double declining rate, the depreciation rate is calculated as $\delta_i = 2/N_i$, where N_i gives the life length of a new i-type asset.[2] The assumptions on asset lives correspond to those in FSO (2006a). The only exception is the category "growing of crops, market gardening, horticulture, farming of animals" for which the authors' own estimate is used.[3] Table 1 summarizes the assumptions on depreciation in the 12-asset case. In the 2-asset case, we use constant aggregate depreciation rates for total structures and total equipment. Since the depreciation rates for the three categories of structures are set uniformly to 4% in the 12-asset case, the same rate is used for total structures. For total equipment, the depreciation rate is set to the aggregate nominal depreciation rate calculated for 1990 from data for the nine equipment categories.[4] This amounts to 13.37% (rounded).

[2] The assumption of a double declining rate is discussed in Oulton and Srinivasan (2003).

[3] As pointed out by the FSO (2006b, page 5), no surveys on asset lives have ever been made in Switzerland. The FSO assumptions on asset lives essentially reflect what is used in economically comparable countries.

[4] Since the depreciation rates are not uniform over all types of equipment, the aggregate depreciation rate from Equation (2.15) is not constant over time. The exception is when the economy is moving along the steady-state growth path.

Table 1: Service lives (L), declining balance rates, (R), and depreciation rates (δ)

Assets	L	R	δ
Growing of crops, market gardening, horticulture, farming of animals	12	2.0	16.7
Fabricated metal products, machinery and equipment (NOGA 28 & 29)	18	2.0	11.1
Office machinery and computers (NOGA 30)	7	2.0	28.6
Electrical machinery and apparatus (NOGA 31)	15	2.0	13.3
Radio, television and communication equipment and apparatus (NOGA 32)	15	2.0	13.3
Medical, precision and optical instruments, watches and clocks (NOGA 33)	15	2.0	13.3
Motor vehicles, trailers and semi-trailers (NOGA 34)	10	2.0	20.0
Other transport equipment (NOGA 35)	20	2.0	10.0
Computer and related activities, media (NOGA 22 & 72)	4	2.0	50.0
Residential buildings	50	2.0	4.0
Other buildings	50	2.0	4.0
Civil engineering	50	2.0	4.0

- End-of-year starting values for the asset stocks $A_{i,t}$ are estimated for 1947 in the 2-asset case and for 1989 in the 12-asset case. The estimates are based on artificial investment data constructed back to 1820 for structures and 1890 for equipment. In the 2-asset case, we assume that gross investment in structures and equipment grew at the rate of GDP before 1948. In the 12-asset case, we assume that gross investment in the three categories of structures and the nine categories of equipment grew at the same rate as total structures and total equipment, respectively, from 1948 to 1990. As in the 2-asset case, all twelve categories are assumed to grow at the rate of GDP before 1948. The end-of-year starting values for total structures and total equipment in 1947 and for the various categories of structures and equipment in 1989 are then obtained by applying the annual depreciation rates from Table 1 to the artificial investment series and adding up over vintages.

Given the stocks of capital for the various types of assets, $A_{i,t}$, we need data on shares in profits, $w_{i,t}$, to calculate aggregate capital services, and shares in wealth, $v_{i,t}$, to calculate the aggregate capital stock. The calculation of these shares requires data on asset prices and the rate of return:

- The asset prices, $P_{i,t}$, are obtained by dividing the nominal investment series by the real investment series. For 1970-1989, artificial series for nominal investment in each of the twelve asset categories are calculated in the same way as for the corresponding volume series. This implies that relative prices are constant among the nine equipment categories and the three structures categories, respectively.

- The rate of return, r_t, is calculated endogenously based on the notion that, in a given period, the total value of capital services corresponds to the total of profits generated by the capital stock (see Equation (2.8)). The National Accounts provide data on the total of gross operating surplus and mixed income ($GOSMI$). Mixed income includes the income of the self-employed which must be attributed to some extent to the labour effort of those persons. To estimate this component, it is assumed that the self-employed on average earn the same labor income as the average employee. This gives $MI = L * Self/Emp$, where L denotes the labour compensation taken from the National Accounts, Emp is the number of employees, $Self$ is the number of self-employed persons, and MI is mixed income. Total profits is then obtained by subtracting MI from $GOSMI$.

4 The 2-asset case: 1970-2005

In this section, we present the results for aggregate capital services and the aggregate capital stock based on data for two assets: structures and equipment. All series are at 1990 prices. Figure 1 displays the results for the period 1970-2005 in levels and growth rates.[5]

The panels at the top of the figure show that both measures of capital have increased steadily over the period under review. The increase amounts to 2.65% per year on average for aggregate capital services and 2.54% per year on average for the capital stock. As can be seen from the bottom-left panel, the annual growth rates range from about 0% to 6%. The same panel suggests that growth in capital services lags growth in the capital stock by one period. This reflects the

[5] Some of the capital measures presented in this paper could be extended to 2006. This is not done in order to have the same end date for all series. At the time of writing, the 12-asset breakdown of investment is available to 2005 only.

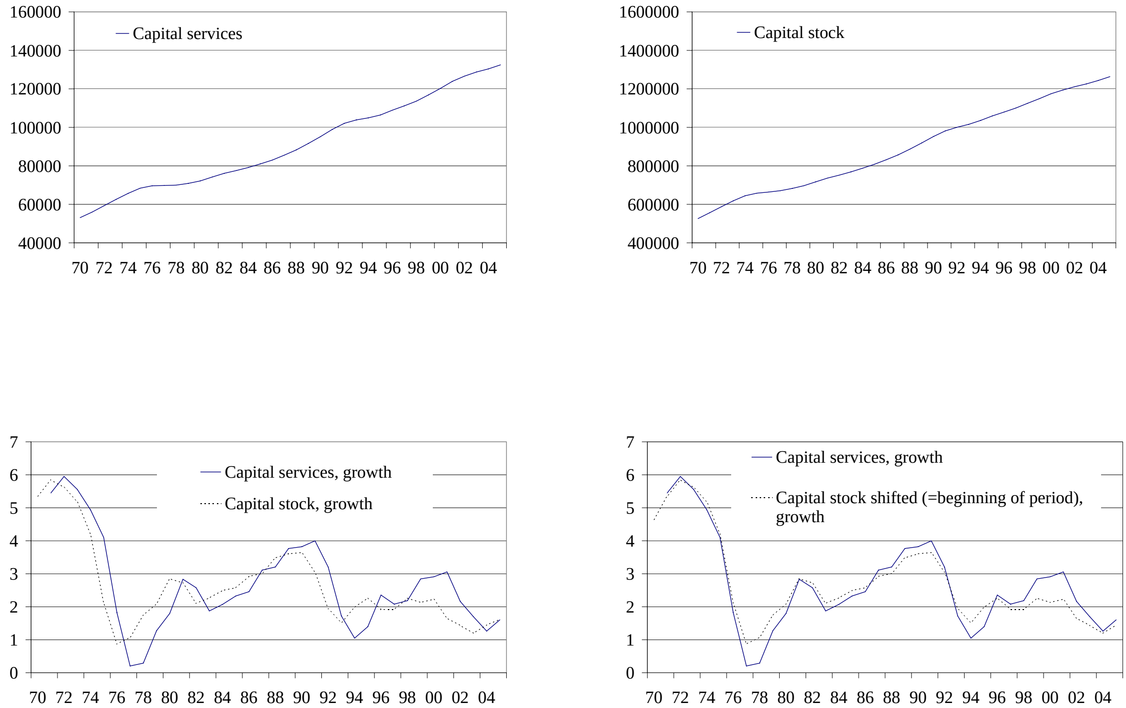

Figure 1: Capital services and capital stock, 2-asset case, levels and growth rates

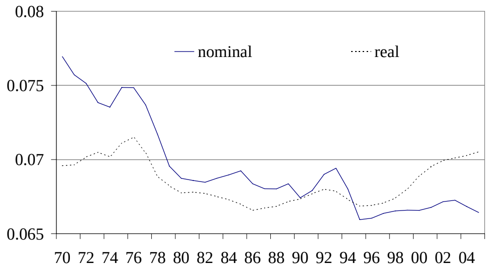

Figure 2: Aggregate depreciation rate, 2-asset case, nominal and real

fact that capital services are calculated based on the capital stock existing at the end of the preceding period. By moving the growth rates of the capital stock backwards one period, the differences between the two series become notably smaller (bottom-right panel).

The results summarised in Table 2 show that the stock of equipment and the stock of structures have grown at about the same speed over the period 1970-2005 (2.60% and 2.50%, respectively). However, the weights attached to the growth rates of the two components have differed substantially between capital services and capital stock. On average, wealth is split 69 to 31 between structures and equipment, while total profits are split 48 to 52. Hence, growth in equipment (structures) gets greater (smaller) weights in the aggregation of capital services than in the aggregation of the capital stock. The difference between the shares in wealth and the shares in profits reflects two factors. First, equipment is subject to more rapid depreciation than structures. Second, inflation has been higher in structure prices than in equipment prices.[6]

The average growth rates for aggregate capital services and the aggregate capital stock differ more substantially when the period 1970-2005 is divided into subperiods. From 1990 to 2005, for example, growth in capital services was 2.38% on average, whereas the capital stock grew at an average rate of 1.90%. The equipment stock grew much more rapidly during this period than the stock of structures (2.50% versus 1.67%). At the same time, the relative price of equipment goods – the asset category with the higher depreciation rate – has fallen. For the equipment stock, this implies high rental price to asset price ratios and high shares in profits compared to shares in wealth.

[6]Prices for structures increased by 2.36% on average over the period 1970-2005, whereas prices for equipment increased by no more than 1.00%.

Table 2: Capital stocks and capital services: 2-asset case 1970-2005

	1970 – 2005		1970 – 1990		1990 – 2005	
	rate	std	rate	std	rate	std
Capital services, growth	2.65	1.39	2.77	1.65	2.38	0.83
Capital stock, growth	2.54	1.20	3.01	1.37	1.90	0.46
Structures						
Capital stock, growth	2.60	1.24	3.30	1.13	1.67	0.60
Share in wealth	68.8	2.9	67.3	3.0	10.9	0.9
Share in profits	48.4	6.6	47.2	7.0	50.0	5.8
Equipment						
Capital stock, growth	2.50	1.85	2.50	2.14	2.50	1.46
Share in wealth	31.2	2.9	32.7	3.0	29.1	0.9
Share in profits	51.6	6.6	52.8	7.0	50.0	5.8

Note: Rate = average rate (growth) or average ratio (share), in percent. Std = standard deviation. Capital stocks refer to the end of the year.

Figure 1 suggests that aggregate capital services are more volatile than the aggregate capital stock. This is confirmed by the standard deviations of the growth rates displayed in Table 2. Essentially, the difference in volatility follows from growth in the stock of equipment being more volatile than growth in the stock of structures. Since growth in the equipment stock has a larger weight in the aggregation of capital services than in the aggregation of the capital stock, this translates into higher volatility in growth rates of capital services.[7]

The effect of the shifts in the composition of the capital stock on the aggregate depreciation rate are displayed in Figure 2. The results are based on Equation (2.14) for the real rate and Equation (2.15) for nominal rate. Both forms of the aggregate depreciation rate declined in the 1970s and 1980s. Since the mid-1990s, they have shown some tendency to rise, reflecting the fact that the stock of assets with short lives (equipment) has increased less rapidly than the stock of assets with long lives (structures). Table 2 shows that growth in the stock of structures exceeded growth in the equipment stock in the period 1970-1990 (3.30% and 2.50%). In the period 1990-2005, it is the other way round, with the equipment stock (2.50%) growing more rapidly than the stock of structures (1.67%).

5 The 12-asset case: 1990-2005

This section presents the benchmark results of aggregate capital services and the aggregate capital stock for the 12-asset case. The 12-asset case differs from the 2-asset case in that structures are broken down in three, equipment in nine categories. In addition, the detailed data underlying the 12-asset case are available from 1990 onwards only. Consequently, the results (and the comparison with the 2-asset case) refer to the period 1990-2005.

In the 12-asset case, aggregate capital services have increased by 2.34% per year on average between 1990 and 2005. Capital services from structures have increased by 1.79%, capital services from equipment by 2.88%. The corresponding average growth rates of the aggregate capital stock are 1.78% for the total, 1.67 for structures, and 2.07% for equipment.

Comparison with the results from the 2-asset case shows higher growth in aggregate capital services and lower growth in the aggregate capital stock (see Figure 3). Yet the pattern of growth rates does not differ greatly between the 2-asset and the 12-asset case. Overall, differences in the dynamics are more marked between capital services and the capital stock than between the

[7] Note also that the shares in profits are more volatile than the shares in wealth.

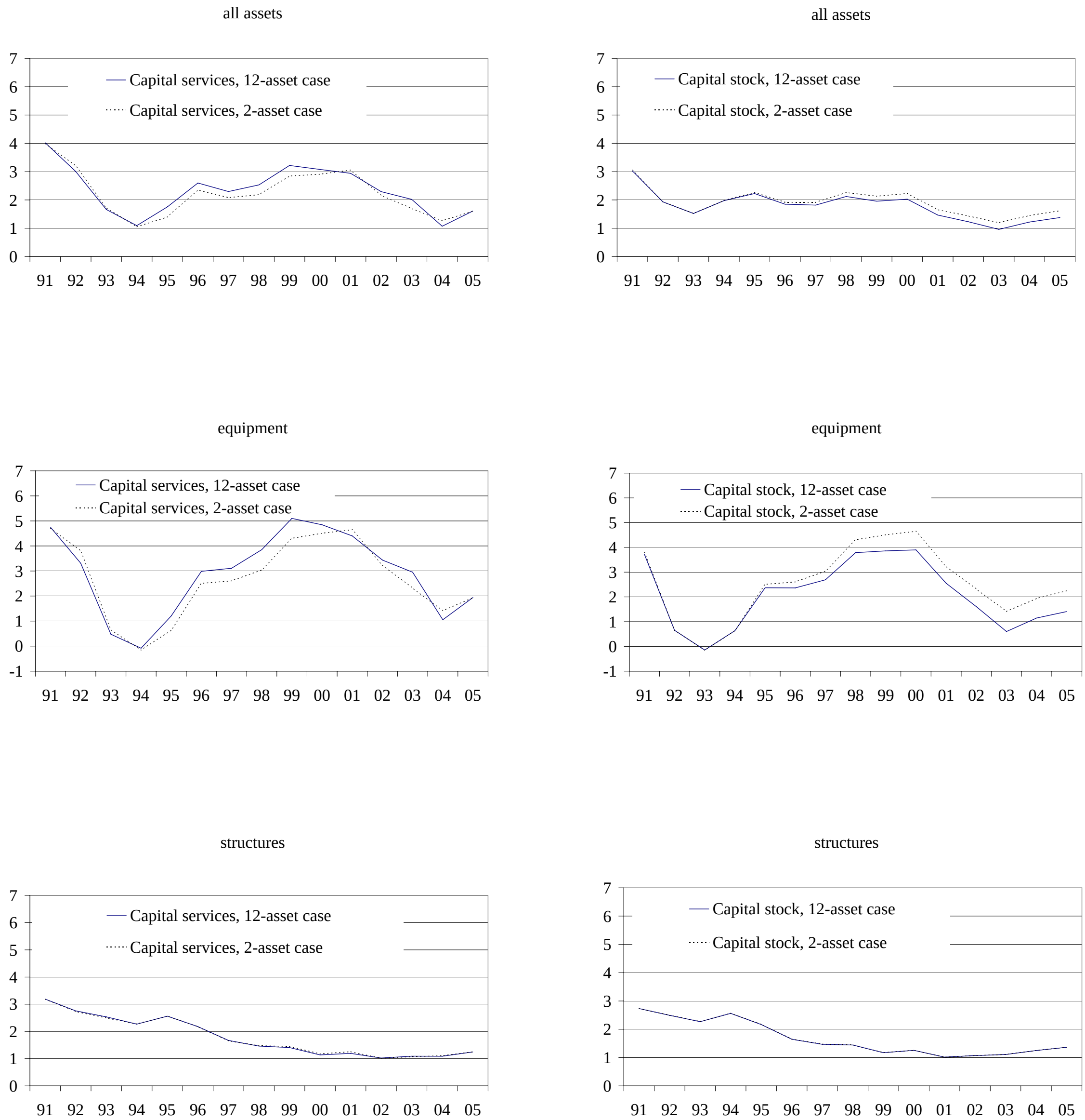

Figure 3: Capital services and capital stock, growth rates, 12-asset case vs. 2-asset case

2-asset and the 12-asset case. Finally, we note again that aggregate capital services are more volatile than the capital stock.

Because the asset stocks of structures and equipment are heterogenous in the 12-asset case, Figure 3 also exhibits the results for structures and equipment. The differences between the 12-asset case and the 2-asset case are negligible for structures where we have assumed that asset lives are the same for all three categories. For equipment, on the other hand, the differences in results are notable suggesting that the composition of the equipment stock have significant effects on the aggregate measures of capital.

To analyse the results in greater detail, it is interesting to look at the growth rates and at the shares in profits and in wealth of the various asset stocks (see Table 3 in the Appendix). The assets with the highest growth rates are software and computers. At the same time, software and computers are the assets with the highest rental price to asset price ratios, reflecting relatively short asset lives and a steep fall of their relative prices. This implies that the discrepancy between growth in aggregate capital services and growth in the aggregate capital stock is driven by these two types of assets. Nevertheless, the weights of computers and software in the aggregation of capital services and the capital stock are modest, despite some substantial gains during the period 1990-2005 in the case of software. The share in profits, $w_{i,t}$, increased from 3.3% in 1990 to 6.1% in 2005 for software, whereas it declined from 3.5% to 3.2% for computers. For the share in wealth, $v_{i,t}$, the changes are from 0.6% to 1.2% and from 1.0% to 0.8%, respectively.

The nominal and the real aggregate depreciation rate are shown in Figure 4. Both rates have increased since the mid-1990s which implies that the stock of assets with short service lives has grown more rapidly than the stock of the assets with longer asset lives. The size of the increase is larger for the real rate than for the nominal rate, and larger in the 12-asset case than in the 2-asset case.

6 The effect of alternative assumptions

The results presented in Section 4 and Section 5 are based on a number of assumptions which may or may not be accurate. In this section, we examine the robustness of the results by presenting measures of aggregate capital services and the aggregate capital stock which are based on alternative sets of assumptions.

The first two sets of alternative assumptions concern the starting values of asset stocks (6.1)

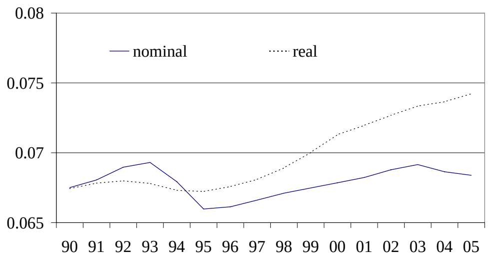

Figure 4: Aggregate depreciation rate, 12-asset case, nominal and real

and the service lives of assets (6.2). Then the method for calculating the user cost of capital (6.3) and the role of ICT prices (6.4) are considered. The former is examined by introducing exogenous (instead of endogenous) rates of return and real (instead of nominal) user cost of capital. The latter is explored by recalculating volumes and weights of ICT assets based on hedonic US price indices. Finally, we look at capital services based on mid-year asset stocks (6.5) and quarterly estimates of capital stocks and capital services (6.6), two variants that are particularly useful in applied empirical work.

It can be shown that when the economy moves along the steady-state path, with constant relative prices and all classes of investment growing at the same constant rate, growth in capital services and growth in the capital stock correspond to growth in investment, and factors like starting values, service lives or methods for calculating the user cost of capital do not affect the results. It is unrealistic, however, to assume that the economy moved along the steady state in the period under review, and therefore it is reasonable and necessary to examine the robustness of the results.

6.1 Starting values

As described in Section 3, the starting values of all asset stocks, $A_{i,0}$, are calculated based on artificial data. To examine the effect of these starting values, we now raise the 1947 values of total equipment and total structures by 100%. Figure 5 shows the results for aggregate capital services and the aggregate capital stock in levels and growth rates over the period 1970-2005. The benchmark results from Section 4 are given for comparison.

The results in levels show that raising the starting values of the asset stocks results in higher

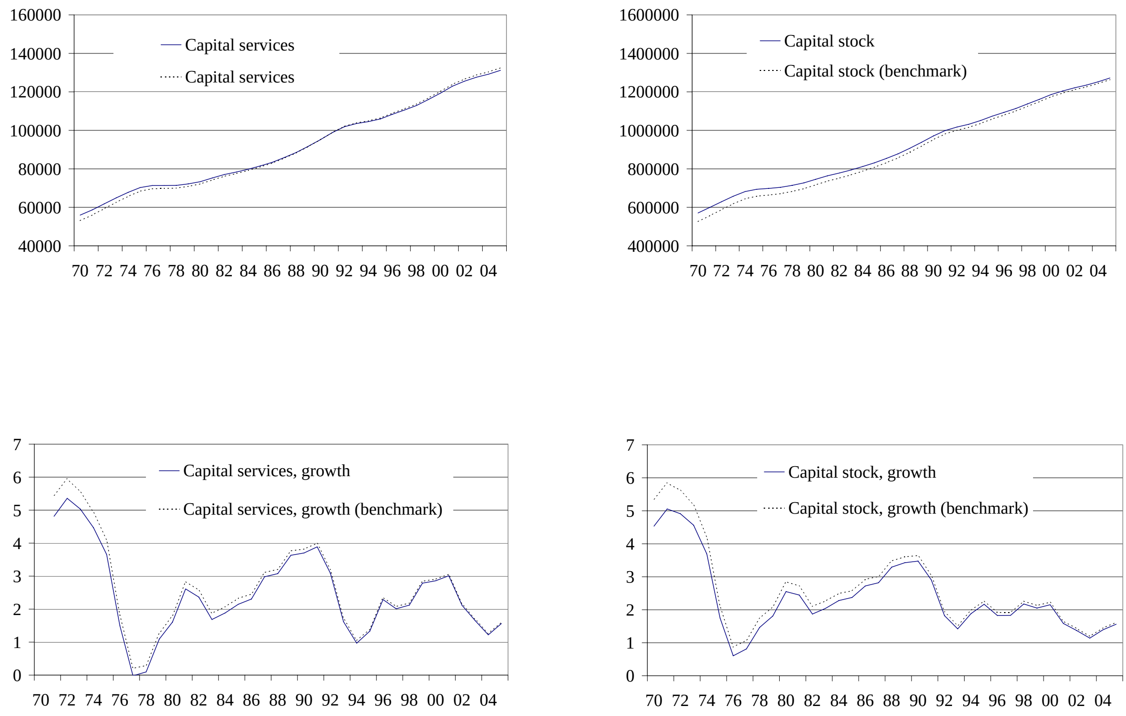

Figure 5: Effect of 100% increase in 1947 asset stocks on capital services and capital stock, 2-asset case

levels of the aggregate capital stock in subsequent years. However, the gap between the alternative series and the benchmark series is narrowing over time. For aggregate capital services, in contrast, the alternative series intersects with the benchmark series in 1990. This reflects the construction of the series, with total capital services set equal to total profits in 1990.

The dynamics of our two measures of capital are little affected by the doubling of the starting values. This reflects the substantial net investment that took place from 1948 to 1970. In 1970, only 1% of the equipment capital stock and 13% of the structures capital stock consisted of investment vintages 1947 or older. Overall, the effect of the change in starting values on growth rates appears to diminish rapidly over time.

As an alternative to linear changes in starting values, we can examine the effect of starting values calculated with different methods. Two additional sets of starting values are considered. First, the estimates by Goldsmith (1980) for stocks of equipment and structures in 1948, re-calculated at 1990 prices, are used as starting values for 1948. Second, estimates based on the steady-state approach are used as starting values for the stocks in 1947.

The steady-state approach can be derived from the perpetual inventory equation. Rewriting Equation (2.2) as

$$g_{i,t} = \frac{A_{i,t} - A_{i,t-1}}{A_{i,t-1}} = -\delta_i + \frac{I_{i,t}}{A_{i,t}} \tag{6.1}$$

and solving for the capital stock $A_{i,t}$ gives

$$A_{i,t} = \frac{I_{i,t}}{\delta_i + g_{i,t}}. \tag{6.2}$$

Along the steady-state growth path, the growth rate of the capital stock, $g_{i,t}$, equals the growth rate of type-i investment. But the economy was hardly in the steady state in 1948. Therefore, following Kamps (2006), we set $g_{i,1948}$ to the average annual growth rate of type-i investment over the period 1948-2000, and $I_{i,1948}$ to its Hodrick-Prescott filtered own value.

It turns out that the resulting starting values deviate moderately from the values used in the calculations reported in Section 4. Goldsmith's (1980) estimates are 33% lower for structures and 27% lower for equipment than our 1948 values. The starting values obtained from the steady-state approach, in turn, are 14% lower for structures and 5% lower for equipment than our 1947 values. Thus, the results for the aggregate capital services and the aggregate capital stock based on these two alternative sets of assumptions are closer to the benchmark series reported in Section 4 than what is shown in Figure 5 for the case with starting values raised by 100%.

6.2 Service lives and depreciation rates

Assumptions concerning the lives of assets vary a great deal from one country to another. As Oulton and Srinivasan (2003) pointed out, these variations probably reflect differences in methodology rather than real economic differences. In this paper, we have opted for the asset lives used by the FSO (2006a) which in turn are based on an assessment of what is used by other countries. In the absence of survey evidence on asset lives for Switzerland, this is a sensible approach, and we do not intend to come up with an alternative scheme. Instead, we examine the sensitivity of the results by extending the asset lives listed in Table 1 by 25%. In the 2-asset case, this reduces the depreciation rate from 4% to 3.2% for structures, and from about 13.4% to 10.7% for equipment.

Figure 6 displays the results for aggregate capital services and the aggregate capital stock in levels and growth rates. The benchmark results from Section 4 are given for comparison. We can

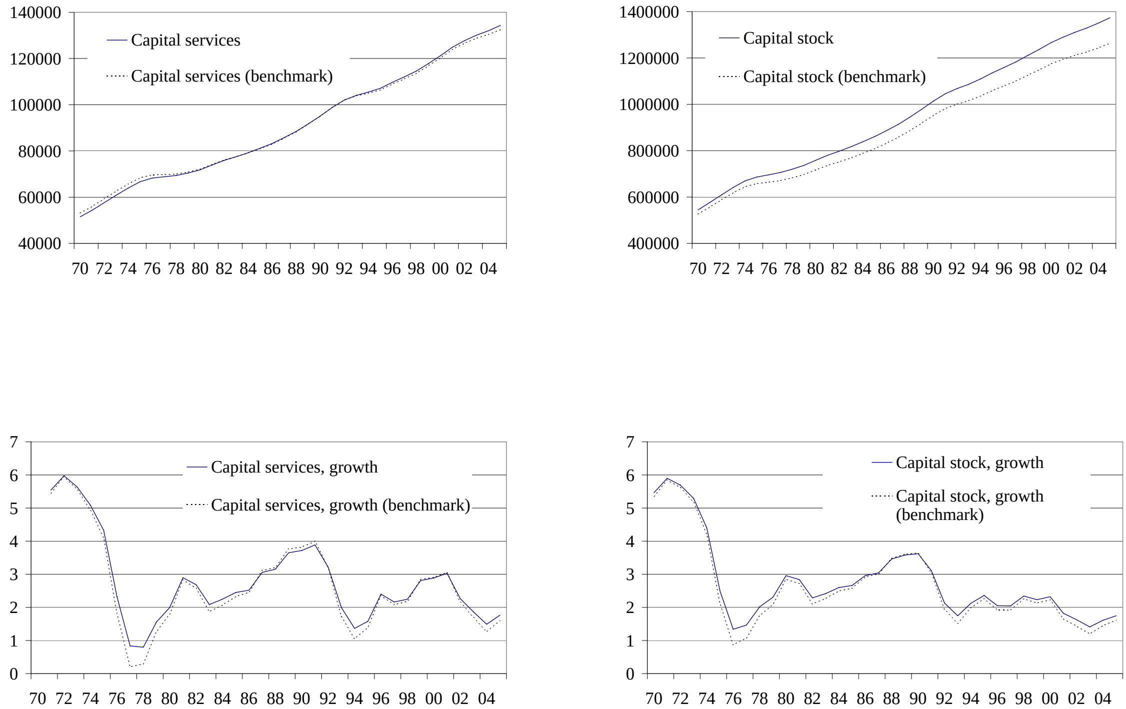

Figure 6: Effect of 25% increase in asset lives on capital services and capital stock, 2-asset case

see that raising asset lives by 25% has a significant effect on the level of the capital stock. The capital stock is shifted up because longer asset lives reduce the share of replacement investments (given a time series for gross investment). The level of aggregate capital services, in contrast, does not shift. Again, the volume series is rotated around its 1990 value because the volume of capital services is set equal to total profits in 1990.

The growth rates of our capital measures change little when asset lives are extended by 25%. Growth in capital services is just 0.1 pp higher on average over the 1970-2005 period. The annual differences vary between -0.1 pp (1989) and 0.6 pp (1977). Effects on the growth rates of the capital stock are similar.[8]

6.3 Rate of return and user cost of capital

To calculate the user cost of capital according to Equation (2.7), we need an estimate of the rate of return. The benchmark results reported in Section 4.1 are based on a rate of return derived endogenously from Equation (2.8). This approach relies on several assumptions which are not strictly realistic. To begin with, markets are assumed to be competitive and returns of scale to be constant to guarantee that the capital services weighted by their user cost of capital exhaust profits. In addition, the assets considered are supposed to account for all sources of the National Accounts' gross operating surplus. Finally, agents are assumed to have perfect foresight regarding future prices and interest rates.

In the literature, two alternatives have been proposed. First, the rate of return is approximated by some market interest rate for which data are available. This is easy to implement but fraught with the problem that the user cost of capital may turn out to be negative. Additionally, there are many market interest rates and it is not clear which one should be picked. Second, nominal user costs of capital are replaced by real user costs of capital. As argued by Diewert (2003), this simplifies matters since expectations on the real rate of return are likely to be less volatile than expectations on the nominal rate of return. In addition, the risk of obtaining negative user cost of capital is reduced. Both routes are taken up in this section.

In the first group of alternative measures of the user cost of capital, we replace the endogenous rate of return from Equation (2.7) by the government bond yield adjusted by some constant risk

[8] The results reported in this section are based on the 1947 starting values used in Section 4. The results do not change significantly when these starting values are re-calculated based on the depreciation rates resulting from the longer asset lives assumed here.

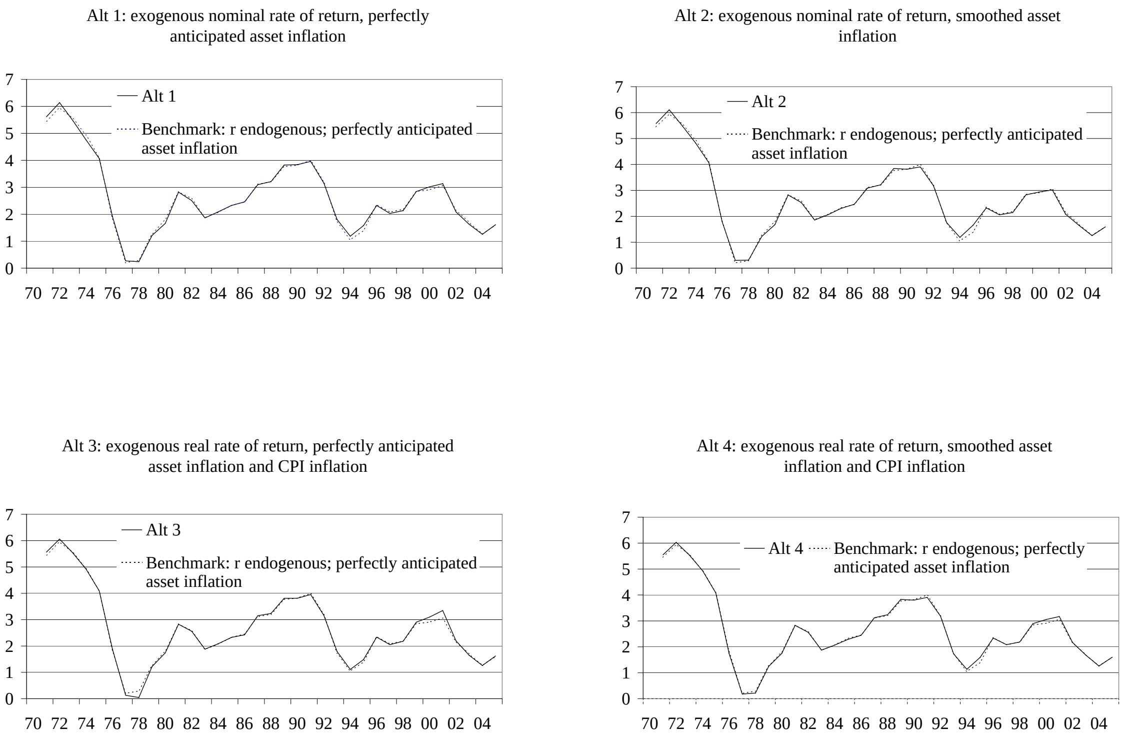

Figure 7: Effect of alternative measures of user cost of capital on growth in capital services: exogenous nominal rate of return (upper row) and exogenous real rate of return (lower row), 2-asset case

premium. Calculations were carried out for risk premiums varying from zero to 4%. It turned out that changes in the constant risk premium appear to have little effect on growth in capital services. Consequently, we will limit ourselves to presenting the results for a 2% risk premium. Two variants are considered. First, asset inflation is assumed to be perfectly anticipated, i.e. the expected one-period asset inflation rate is set equal to the asset inflation observed over that period ex post. This assumption on asset inflation corresponds to the one adopted in Section 2. Second, the expected one-period asset inflation rate is set equal to the 3-year moving average of the asset inflation observed ex post.

The second group of alternative measures refers to user cost of capital in real terms. The starting point for the derivation of the formula is Equation (2.7). Adding and subtracting 1 on the right hand side of Equation (2.7) gives, after some rearranging,

$$U_{i,t} = [1 + r_t - (1 - \delta_i)(1 + q_{i,t})]P_{i,t-1}. \tag{6.3}$$

Let π_t denote the rate of change in consumer prices. Dividing both sides of Equation (6.3) by $1 + \pi_t$ yields

$$\frac{U_{i,t}}{1 + \pi_t} = [\frac{1 + r_t}{1 + \pi_t} - \frac{(1 - \delta_i)(1 + q_{i,t})}{1 + \pi_t}]P_{i,t-1}. \tag{6.4}$$

Defining $U^*_{i,t} = U_{i,t}/(1 + \pi_t)$, $1 + r^*_t = (1 + r_t)/(1 + \pi_t)$ and $1 + q^*_{i,t} = (1 + q_{i,t})/(1 + \pi_t)$, and assuming the real rate of return to be constant, $r^*_t = r^*$, the user cost of capital in real terms can be written as

$$U^*_{i,t} = [1 + r^* - (1 - \delta_i)(1 + q^*_{i,t})]P_{i,t-1} \tag{6.5}$$

or

$$U^*_{i,t} = [r^* + \delta_i - q^*_{i,t} + \delta_i q^*_{i,t}]P_{i,t-1}. \tag{6.6}$$

We set the real rate of return to r^*=3%. This is below the 4% assumed by Diewert (2003) in his study on Canadian data. The lower rate can be justified on the ground that economic growth and ex-post real interest rates have been lower in Switzerland than in many other industrialised countries during the period under review. Again, two variants are considered. First, perfect foresight is assumed such that the expected one-period inflation rates for asset prices and consumer prices correspond to their ex post outcome. Second, the expected one-period inflation rates are approximated by the 3-year averages of these two variables observed ex post.

The results for the 2-asset case over the period 1970-2005 are summarised in Figure 7. The four panels show the effect of applying an alternative measure of the user cost of capital on

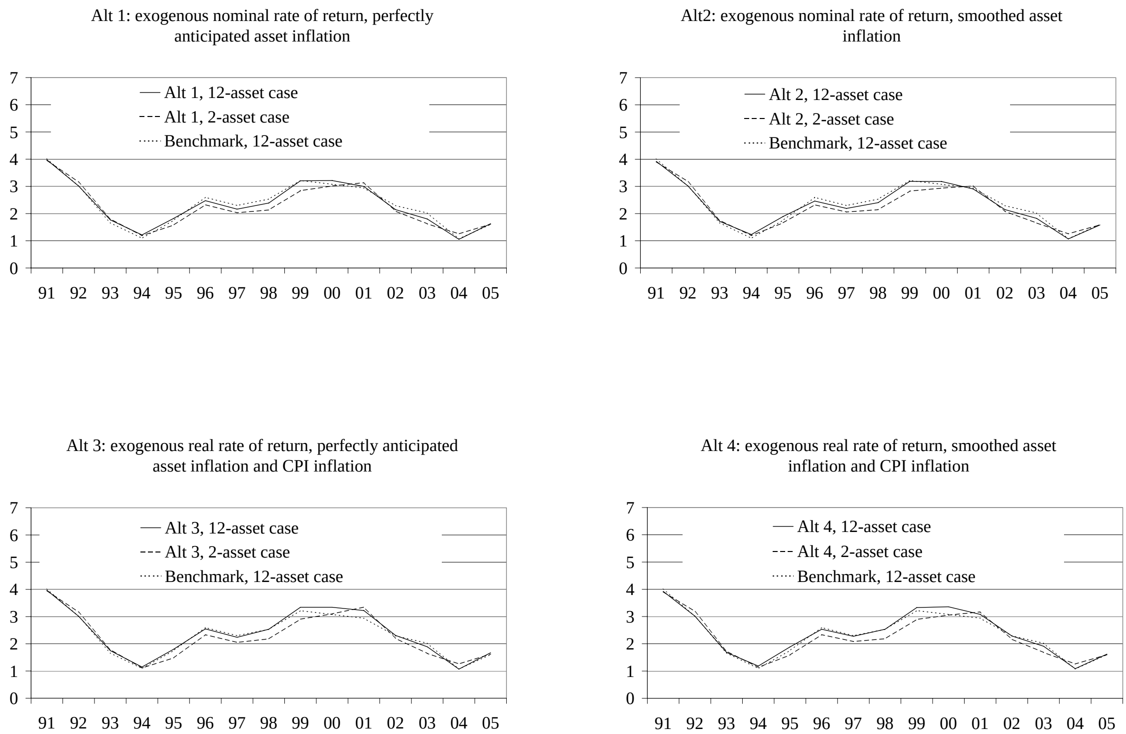

Figure 8: Effect of alternative measures of user cost of capital on growth in capital services: exogenous nominal rate of return (upper row) and exogenous real rate of return (lower row), 12-asset case

the volume of capital services. The benchmark results from Section 4 are given for comparison. Overall, the alternative measures of user cost of capital appear to have little effect on the results.

Figure 8 shows the results for the 12-asset case over the period 1990-2005. The corresponding results of the 2-asset case and the benchmark results of the 12-asset case (reported in Section 5) are given for comparison. Overall, the results suggest again that the method for calculating the user cost of capital does not have important effects on the dynamics of aggregate capital services. An exception are the years around 2000, where notable differences occur when real user cost of capital are used to construct aggregate capital services. Differences are significantly larger on the whole when the comparison is with the corresponding results from the 2-asset case. Thus, Figure 8 suggests that the differences in results between the 2-asset case and the 12-asset case are more important than differences caused by the method for calculating the user cost of capital.

6.4 Price indices for ICT goods

ICT goods differ in several aspects from the other assets. In particular, they have shorter asset lives and their relative prices have decreased rapidly over the years. Both characteristics reflect the rapid technological progress in this sector of industry.

Prices of goods with quality changes are notoriously hard to measure. Statistical agencies tackle the problem in various ways.[9] As a result, price indices of ICT goods tend to differ widely from one country to another. Since this reflects differences in methodology rather than economic reality, various authors have tried to make the measures comparable by substituting the US price indices of ICT goods for the corresponding national indices (see Schreyer (2002), and Oulton and Srinivasan (2003)).

The US Bureau of Economic Analysis (BEA) has developed and used hedonic price indices to quality adjust the deflators for computers and software. In principle, this is the technique preferred by most economists on theoretical grounds. But hedonic price indices are rare in practice because they are very data intensive. Hence, it makes good sense to use the US ICT price deflators as a rough approximation of the true price indices and to examine how results respond to replacing the national ICT price deflators by the corresponding US indices.[10]

[9]Triplett (2004) describes quality adjustments in conventional price index methodologies and in hedonic price indices.

[10]The three US price deflators are not purely hedonic. Jorgenson and Stiroh (2000) argue that the US deflator for communication equipment may underestimate the fall in quality-adjusted prices because some

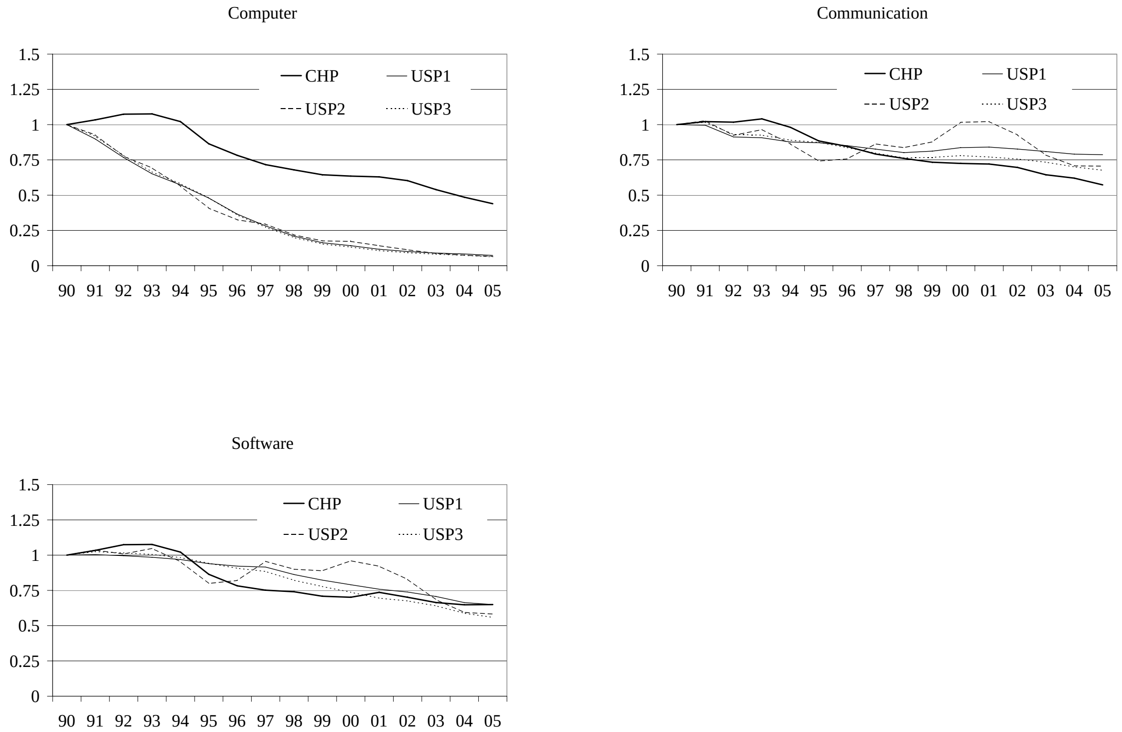

Figure 9: Swiss vs. US deflators

To examine the role of ICT price indices in the 12-asset case, we recalculate aggregate capital services and the capital stock based on the assumption that the prices of computers (NOGA30), communication equipment (NOGA32), and software (NOGA22+72) followed the path of the corresponding US price deflators. Following Schreyer (2002), three variants of the US price deflators of ICT goods are considered: (i) the US indices without any further adjustments (USP1), (ii) the US indices adjusted by the nominal USD-CHF exchange rate (USP2), (iii) the US indices adjusted for the price level ratio of the two countries, with price levels measured by GDP price deflators (USP3). Figure 9 shows these three price indices together with the corresponding price deflators from Switzerland's National Accounts. The results indicate that the US deflators for communication equipment and for software do not differ greatly from the corresponding Swiss deflators. There is a substantial difference, however, between the price deflators of computers, with the three US deflators falling much more rapidly than the Swiss deflator.

Figure 10 shows the growth rates of aggregate capital services and the aggregate capital stock

components of this index are not based on the hedonic approach.

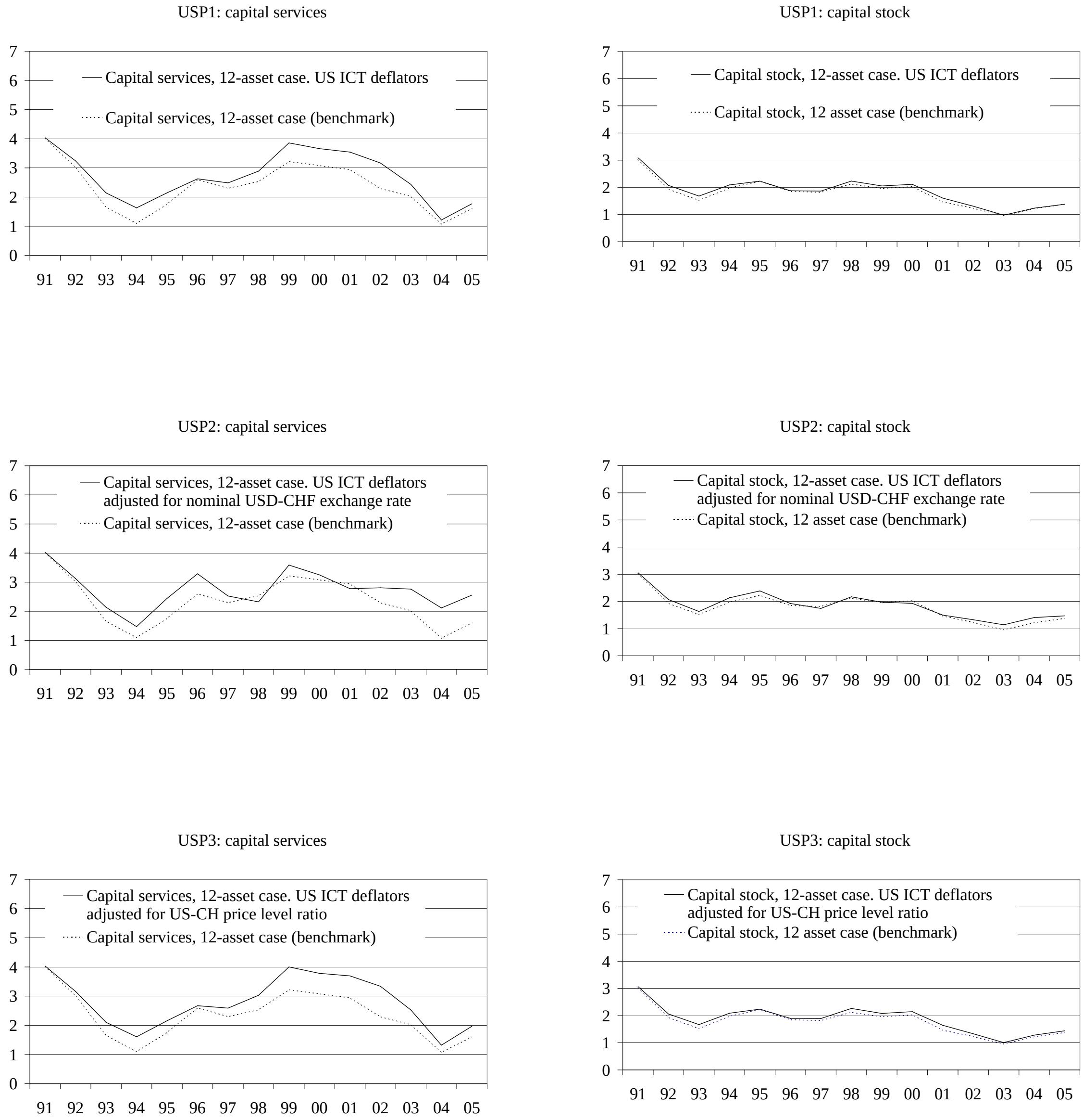

Figure 10: Effect of alternative ICT deflators on growth in capital services and the capital stock

over the period 1990-2005, based on the three variants of the US price deflators of ICT goods. The results reported in Section 5 are given for comparison. Overall, the results suggest that replacing the national ICT price deflators by the US indices raises growth in aggregate capital services significantly. By contrast, the results for growth in the aggregate capital stock show much smaller differences between the various series. The reason is that, for the three ICT categories, the shares in wealth are much smaller than the shares in profits (see Appendix B for average shares in profits and wealth).

6.5 Mid-year asset stocks

We have assumed so far that investment in period t is not depreciated and does not provide capital services in t. According to Equations 2.2 and 2.3, both the depreciation and the provision of capital services begin in $t+1$ only. If period t is relatively long, this setting gives reasonable results for investments made at the end of the period. But for investments made at the beginning of the period, it implies that they neither depreciate nor provide capital services for a full period. For this reason, the underlying assumptions have been criticised as inadequate in the context of annual data (see e.g. Oulton and Srinivasan (2003)).

Alternatively, we can make the explicit assumption that investment is spread evenly across the year. In this case, i-type capital stocks and capital services are determined by

$$B_{i,t} = I_{i,t} + (1-\delta_i)B_{i,t-1}, \tag{6.7}$$

$$A_{i,t} = (1-\delta_i/2)B_{i,t}, \tag{6.8}$$

$$K_{i,t} = \bar{A}_{i,t} = (A_{i,t-1}A_{i,t})^{1/2}, \tag{6.9}$$

where $A_{i,t}$ is the stock of i-type asset at the end of period t and $\bar{A}_{i,t}$ is the stock of i-type asset in the middle of period t; $B_{i,t}$ is the stock of i-type asset at the end of period t when investment are assumed to be done at the end of the period (see Oulton and Srinivasan (2003) and BEA (2003)).

Figure 11 shows growth rates of aggregate capital services and the aggregate capital stock calculated based on Equations (6.7) to (6.9), instead of Equations (2.2) and (2.3), and $\bar{A}_{i,t}$ replacing $A_{i,t}$ in Equation (2.11). The results from Sections 4 and 5 are given for comparison. The volatility of the series based on mid-year stocks is smaller than that of the benchmark series. And the turning points are in the same period for capital services and the capital stock in the

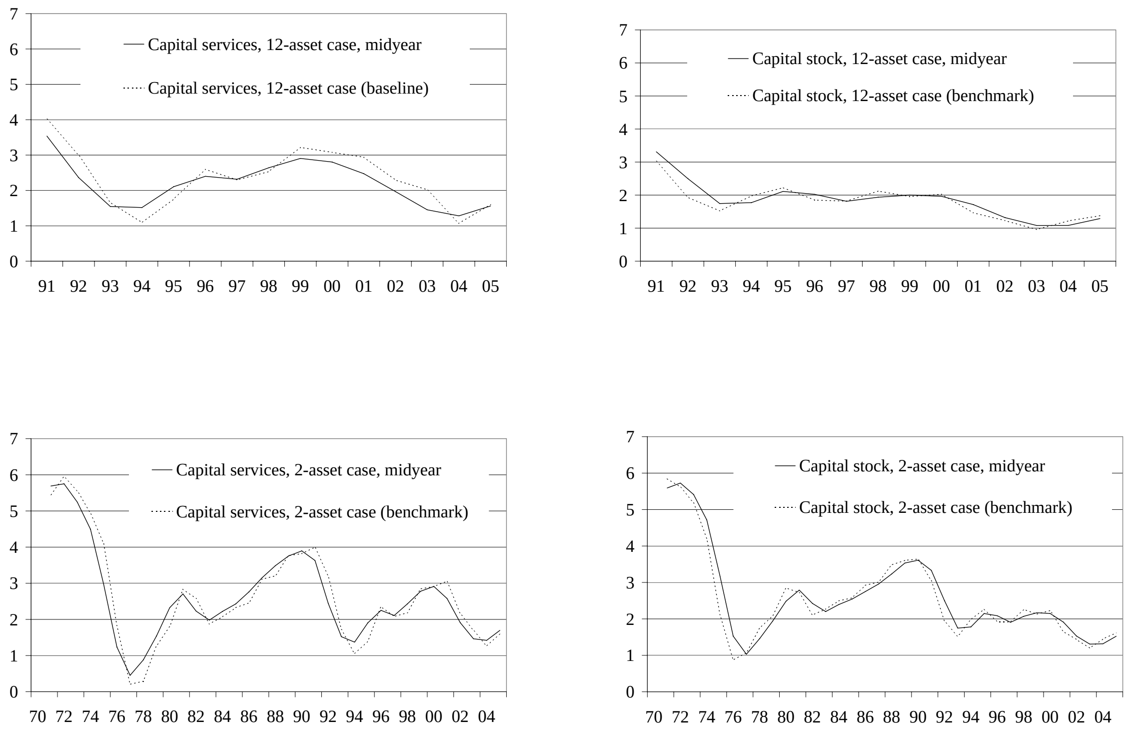

Figure 11: Capital services and capital stock, growth rates, 2-asset case and 12-asset case: midyear vs. end of year (benchmark case)

mid-year series (due to $K_{i,t} = \bar{A}_{i,t}$), whereas capital services lag the capital stock by one period in the measures based on end-of-period asset stocks (due to $K_{i,t} = A_{i,t-1}$).

6.6 Quarterly estimates

In principle, quarterly estimates of capital stocks and capital services can be derived along the same lines as the corresponding annual measures presented in Sections 4 5.[11] The main difficulty are the data requirements. Whereas quarterly data on investment in total equipment and total structures (2-asset case) are readily available, data on gross operating surplus and on the 12-asset breakdown of investment are available only annually.

There are various ways to construct quarterly data from annual data. The results presented

[11] The objection raised in Section 6.5 has less weight when data are quarterly. Thus, we follow Oulton and Srinivasan (2003) and apply the methodology described in Section 2.

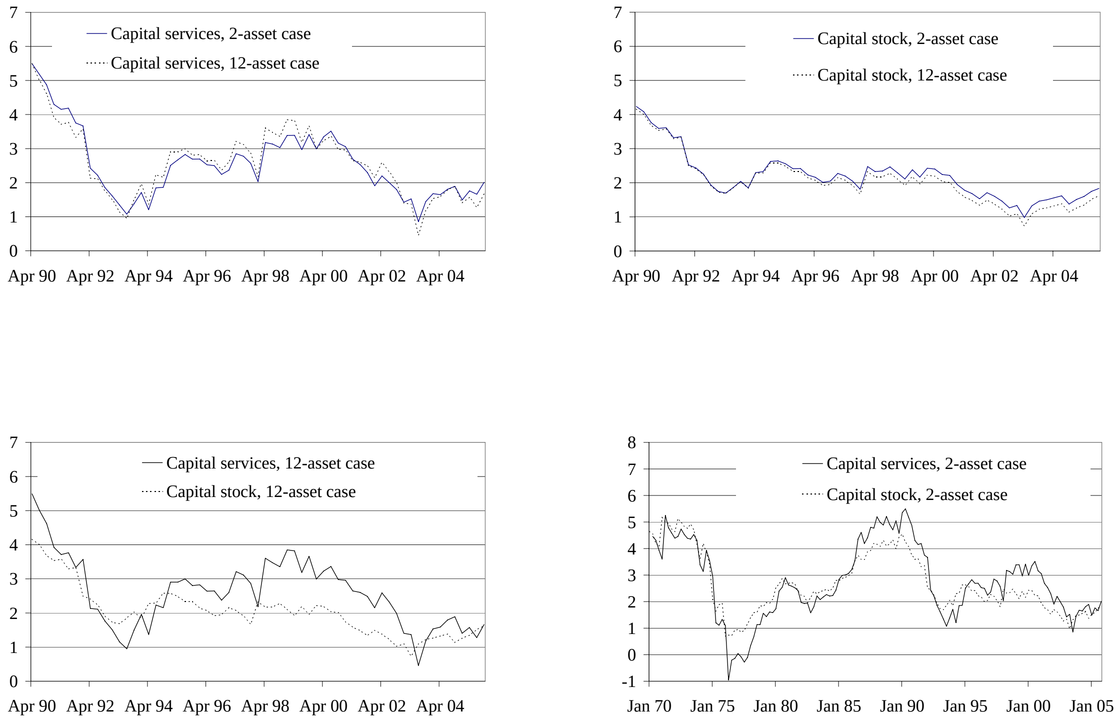

Figure 12: Capital services and capital stock, growth rates, 2-asset case and 12-asset case: quarterly data

below are based on quarterly data for investment volumes derived from the corresponding annual series with the Chow-Lin method. The indicator series are total structures investment for the three structures investment series and total equipment investment for the nine equipment investment series. The twelve asset stocks are then calculated based on the quarterly investment volumes and starting values derived from annual data for 1964. The quarterly investment prices are obtained likewise by applying the Chow-Lin method to the annual nominal investment data and dividing the resulting quarterly series by the volume series. Combined with quarterly data for gross operating surplus (obtained by dividing the annual data equally among the four quarters of the year), this allows us to calculate quarterly user costs of capital for the twelve asset stocks.

Figure 12 displays the results in terms of annualised quarterly growth rates. The four charts provide a side-by-side comparison of the 2-asset case versus the 12-asset case, and of capital services versus capital stock.

7 Concluding remarks

In this paper, we have calculated measures of aggregate capital services for the 2-asset case over the period 1970-2005, and for a more detailed breakdown of investment data by 12 categories over the period 1990-2005. These measures have been compared to the corresponding results for the aggregate capital stock, which stands for the wealth concept of capital. The results suggest that the dynamics of capital services calculated from the 12-asset data breakdown are picked up reasonably well by the capital services from the 2-asset breakdown, and even the capital stock from either the 12-asset or 2-asset breakdowns. The differences are not negligible, however, suggesting that a series of capital services calculated from the 12-asset breakdown should be used as a measure of capital input as long as the issue at hand does not require capital data starting earlier than 1990.

The calculations for various sets of alternative assumptions suggest that the growth rates of capital services are rather insensitive to changes in the assumptions on starting values and asset lives. The method of calculating the user cost of capital has somewhat larger (but still modest) effects on the results. On the whole, the potential mismeasurement of ICT price deflators might well have been the largest source of uncertainty in recent years.

There are various aspects of capital measurement that we have not explored in this paper:

- Geometric depreciation has been assumed throughout the work presented here. While there are good arguments for this choice, other forms of depreciation patterns exist and are discussed in the literature (one-hoss-shay, linear, etc.). Diewert (2003) has examined the effect of these assumptions in data for Canada. His findings suggest that the results do not depend critically on the assumption concerning the form of depreciation.

- The capital goods considered in this paper are fixed produced assets. Inventories are not considered due to lack of data. Land is not considered either. In a study on Japan, Diewert et al. (2005) have pointed out that the neglect of land may have a sizable effect on the average growth rate of capital services. Since the volume of land does not usually change much over time, its inclusion reduces growth in the aggregate capital measures. Also, the inclusion of land (and of inventories) may lead to more accurate results for the implied rate of return calculated from gross operating surplus.

- The effect of the tax system on the user cost of capital has not been considered in this paper (see Hall and Jorgenson (1967) for an analysis of user cost of capital, taking into account the role of taxes). Again, the reason is lack of data.

Lastly, we would reemphasise the fact that our results refer to the full economy (with the qualifications described above). Measures of capital for the sectors of the economy cannot be derived for Switzerland, as investment data broken down by industries are not available. What can be calculated, however, are measures of capital that exclude specific forms of fixed assets. For example, residential investment is sometimes excluded from measures of capital input used to calculate potential output growth. Or aggregate capital services are computed for the equipment assets alone and for the structures alone. These aggregates can be calculated easily within the framework described in this paper, which assumes an economy-wide rate of return.

References

Andrist, F., Anderson, R. and Williams, M.: 2000, Real output in Switzerland: New estimates for 1914-47, *Federal Reserve Bank of St. Louis Review* .

BEA: 2003, Methodology, fixed assets and consumer durable goods in the United States, 1925-1997, *Bureau of Economic Analysis.*

Diewert, W.: 2003, Measuring capital, *NBER Working Paper 9526.*

Diewert, W., Mizobuchi, H. and Nomura, K.: 2005, On measuring Japan's productivity, 1955-2003, *Uuniversity of British Columbia, Department of Economics, Discussion Paper No. 05-22.*

Diewert, W. and Schreyer, P.: 2006, The measurement of capital, *draft entry to the New Palgrave Dictionary of Economics.*

FSO: 2006a, Productivité multifactorielle - rapport méthodologique, *Swiss Federal Statistical Office, working paper.*

FSO: 2006b, Stock de capital nonfinancier - rapport méthodologique, *Swiss Federal Statistical Office, working paper.*

Goldsmith, R.: 1980, A tentative secular national balance sheet for Switzerland, *Schweizerische Zeitschrift für Volkswirtschaft und Statistik* **116**, 175–87.

Hall, R. and Jorgenson, D.: 1967, Tax policy and investment behavior, *American Economic Review* **57**, 391–414.

Hulten, C. R.: 1990, *The measurement of capital*, in: Fifty years of economic measurement, E.R. Berndt and J.E. Triplett (eds.), Chicago: Chicago University Press.

Hulten, C. and Wykoff, F.: 1996, Issues in the measurement of economic depreciation: introductory remarks, *Economic Inquiry* **34**, 10–23.

Jorgenson, D.: 1963, Capital theory and investment behavior, *American Economic Review* **3**, 247–59.

Jorgenson, D.: 1989, *Capital as a factor of production*, in: Technology and Capital Formation, D.W. Jorgenson and R. Landau (eds.), Cambridge: The MIT Press.

Jorgenson, D. and Christensen, L.: 1969, The measurement of U.S. real capital input, *Review of Income and Wealth* **15**, 293–320.

Jorgenson, D. and Griliches, Z.: 1967, The explanation of productivity change, *Review of Economic Studies* **34**, 349–83.

Jorgenson, D. and Stiroh, K.: 2000, Raising the speed limit: U.S. economic growth in the information age, *Brookings Papers on Economic Activity* **1**, 125–236.

Kamps, C.: 2006, New estimates of government net capital stocks for 22 OECD countries, 1960-2001, *IMF Staff Papers* **53**, 120–150.

Maddison, A.: 2006, *The World Economy*, OECD, Development Centre Studies.

OECD: 2001a, *OECD Manual - measuring capital: Measurement of capital stocks, consumption of fixed capital and capital services*, Paris: Organization for Economic Co-operation and Development.

OECD: 2001b, *OECD manual - measuring productivity: Measurement of aggregate and industry-level productivity growth*, Paris: Organization for Economic Co-operation and Development.

Oulton, N. and Srinivasan, S.: 2003, Capital stocks, capital services, and depreciation: An integrated framework, *Bank of England Working Paper 192.*

Ritzmann-Blickenstorfer, H.: 1996, *Historical Statistics of Switzerland*, Zurich: Chronos.

Schreyer, P.: 2002, Computer price indices and international growth and productivity comparisons, *Review of Income and Wealth* **48**, 15–31.

Schreyer, P., Diewert, W. and Harrison, A.: 2005, Cost of capital services and the National Accounts, *OECD STD/NAES(2005)17.*

Triplett, J.: 2004, Handbook on hedonic indexes and quality adjustments in price indexes: Special application to information technology products, *OECD Science, Technology and Industry Working Papers, 2004/9.*

A Data: definitions and sources

Asset lives. Source: FSO (2006b) for all categories except "growing of crops, market gardening, horticulture, farming of animals" for which the authors' own estimate is used (see Table 1).

Consumer price index. Average of monthly observations. Source: FSO for 1913-2005; Ritzmann-Blickenstorfer (1996) for 1851-1913.

Exchange rate. USD-CHF exchange rate, average of daily observations. Source: SNB.

Government bond yield. Average of daily observations. Source: SNB. We approximate the exogenous nominal ex-ante rate of return by the average government bond yield for the previous period.

Gross capital formation (investment), volumes and prices. 1948-1990 National Accounts for structures and equipment. 1990-2005 National Accounts (ESVG95) for three components of structures ("residential buildings", "non-residential buildings", "civil engineering") and nine components of equipment ("fabricated metal products, machinery and equipment", "office machinery and computers", "electrical machinery and apparatus", "radio, television and communication equipment and apparatus", "medical, precision and optical instruments, watches and clocks", "motor vehicles, trailers and semi-trailers", "other transport equipment", "computer and related activities, media", and "growing of crops, market gardening, horticulture, farming of animals"). Before 1948: growth rates of investment volumes are approximated by estimates of GDP growth taken from Andrist et al. (2000) for 1913-1948, Ritzmann-Blickenstorfer (1996) for 1851-1913 (gross value added deflated by CPI), and Maddison (2006) for 1820-51 (based on estimates of the level of real GDP for 1820 and 1851). Growth rates from before 1948 and for 1948-1990 are chain linked to the 1990 data from ESVG95. Volumes are at chained 1990 prices.

Gross operating surplus. "Gross operating surplus and mixed income" 1990-2005 from National Accounts (FSO), for 1970-1990 from OECD National Accounts statistics. Mixed income calculated based on the information on "labour compensation" from the same sources and on the number of self employed and family members from the Labour Force Statistic (FSO).

Price deflators for GDP. Source: FSO for Switzerland, Bureau of Economic Analysis for United States.

US price deflators for ICT investment. Price indexes of private fixed investment in equipment and software: "computers", "software", "communication equipment". Source: Bureau of Economic Analysis.

B Asset stocks, shares in profits and in wealth: 12-asset case 1990-2005

Table 3 summarises the results for the 12-asset case in terms of average annual growth rates and standard deviations over the period 1990-2005 and two subperiods (1990-2000, 2000-2005). Note that shares in profits are calculated based on $A_{i,t-1}$, whereas shares in wealth are calculated based on $A_{i,t}$ (see Equations (2.3), (2.10) and (2.12)).

Table 3: Components of capital measures: 12-asset case 1990-2005

	1990 – 2005		1990 – 2000		2000 – 2005	
	rate	std	rate	std	rate	std
Residential buildings						
Capital stock	2.09	0.68	2.28	0.65	1.70	0.64
Share in wealth	29.2	0.8	29.0	0.8	29.8	0.4
Share in profits	20.7	2.2	20.9	2.6	20.4	1.2
Other buildings						
Capital stock	0.84	0.76	1.06	0.85	0.42	0.24
Share in wealth	27.9	1.1	28.5	0.8	26.7	0.3
Share in profits	20.0	2.4	20.7	2.5	18.6	1.1
Civil engineering						
Capital stock	2.49	0.94	3.02	0.63	1.44	0.35
Share in wealth	13.4	0.8	13.0	0.5	14.3	0.3
Share in profits	9.3	2.2	9.4	2.2	9.1	2.5
Growing of crops, farming of animals						
Capital stock	0.47	1.91	1.00	1.42	-0.56	2.49
Share in wealth	0.1	0.0	0.1	0.0	0.1	0.0
Share in profits	0.2	0.1	0.2	0.1	0.2	0.1
Fabricated metal products, machinery						
Capital stock	1.25	0.91	1.36	1.10	1.03	0.29
Share in wealth	15.5	0.5	15.7	0.5	15.1	0.1
Share in profits	21.8	3.1	21.9	3.7	21.7	1.7
Office machinery and computers						
Capital stock	5.80	3.57	6.18	4.12	5.04	2.29
Share in wealth	1.0	0.1	1.0	0.0	0.9	0.1
Share in profits	3.4	0.4	3.4	0.4	3.5	0.2

Table 3, continued

	1990 – 2005		1990 – 2000		2000 – 2005	
	rate	std	rate	std	rate	std
Electrical machinery and apparatus						
Capital stock	0.75	1.89	1.57	0.94	-0.88	2.37
Share in wealth	3.0	0.3	3.2	0.2	2.7	0.1
Share in profits	5.3	0.9	5.6	0.9	4.5	0.5
Radio, TV and communication						
Capital stock	2.78	2.18	2.44	2.01	3.46	2.58
Share in wealth	2.0	0.3	2.1	0.2	1.7	0.1
Share in profits	3.8	0.6	3.9	0.6	3.6	0.3
Various instruments and watches						
Capital stock	3.90	2.42	3.65	2.28	4.40	2.90
Share in wealth	3.4	0.2	3.3	0.2	3.5	0.1
Share in profits	6.0	0.8	6.0	1.0	5.9	0.5
Motor vehicles, trailers						
Capital stock	1.61	2.38	1.55	2.73	1.72	1.76
Share in wealth	0.9	0.0	0.8	0.0	0.9	0.0
Share in profits	1.9	0.2	1.9	0.2	2.0	0.1
Other transport equipment						
Capital stock	2.53	5.27	4.64	5.22	-1.57	1.63
Share in wealth	2.8	0.4	2.6	0.4	3.2	0.2
Share in profits	3.2	1.1	2.6	0.8	4.3	0.5
Software, media						
Capital stock	9.25	8.66	10.11	10.16	7.54	4.81
Share in wealth	0.9	0.2	0.7	0.2	1.1	0.0
Share in profits	4.4	1.4	3.5	0.7	6.0	0.5

Note: Rate = average rate (growth) or average ratio (share), in percent. Std = standard deviation. Capital stocks refer to end of period.

C Comparison with FSO series of aggregate capital services and the aggregate capital stock

In October 2006, the FSO published measures of growth in multi-factor productivity for the years 1991 to 2004; see FSO (2006a). One year later, the data were revised and updated to 2005. These productivity measures are based on estimates of growth in capital services. Also, in October 2006, the FSO published estimates of the gross capital stock; see FSO (2006b). Estimates of the net capital stock were first published at the end of 2007.[12]

The FSO estimates of growth in *aggregate capital services* and the estimates reported in Section 5 are based on the same approach. Both use the perpetual inventory method, geometric depreciation rates, and a Törnqvist index to aggregate over the various types of assets. Moreover, both use about the same investment data and do not consider inventories and land. The differences are minor and can be summarised as follows:

Timing. The FSO assumes that the capital services in period t are proportional to the asset stock at the end of t, i.e. $K_{i,t} = A_{i,t}$. By contrast, we assume $K_{i,t} = A_{i,t-1}$ (see Equation (2.3)).

Truncated depreciation. The FSO assumes that a capital good can be dropped from the stock once the efficiency is less than 10% of its initial level. By contrast, the capital good will continue to be part of the capital stock in our calculation (although its weight approaches zero with time). Consequently, the FSO does not need to construct the starting values $A_{i,0}$ in Equation (2.2), and the artificial data series of gross capital formation constructed for the years before 1990 are shorter.

User cost of capital. The user costs of capital utilised by the FSO are defined in real terms, and the underlying real rate of return is modelled as a constant exogenous ex-ante rate. This constant rate is calculated as the average between the real government bond yield and the endogenous real rate of return, both computed as averages over 1990-2005. By contrast, we utilise nominal user costs of capital, and the rate of return is an ex-post rate calculated endogenously (real user costs of capital and exogenous rates of return are examined as alternatives in Section 6).

Data on agricultural assets. The FSO data differs in content and range from the data we have used. Agricultural assets are broken down into six categories with varying asset lives. In contrast, we use a single category. Note, however, that the share of agricultural assets in total

[12]see http://www.bfs.admin.ch/bfs/portal/de/index/themen/04/02/04/key/Stock_cap.html.

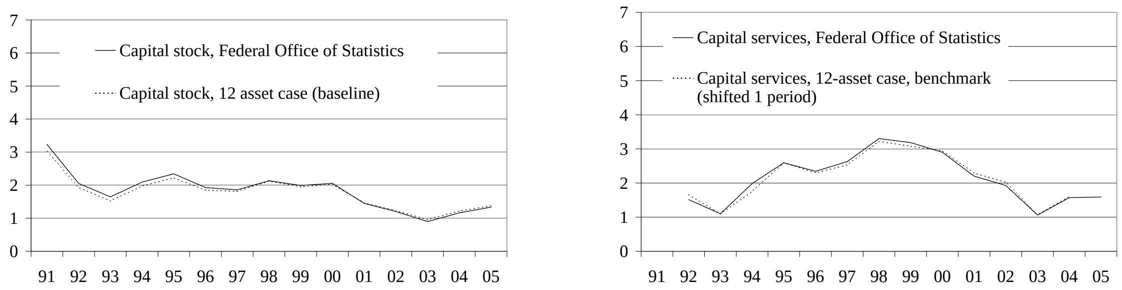

Figure 13: Comparison FSO estimates vs. benchmark estimates (12-asset case), growth rates

profits is just about 0.2% in both calculations.

Structures before 1948. The FSO calculates artificial data of structures investment based on the elasticity of investment with respect to GDP (estimated with a regression over 1948-2005) and GDP data for the period 1890-1948. The constant of the regression is not considered in the calculation of the artificial pre-1948 investment data. In contrast, we have assumed that growth in construction investment corresponds to growth in real GDP (over the period 1820-1948).

For the calculation of the *aggregate capital stock* (= net capital stock), the FSO does not use the same vintage truncation as for capital services. In addition, the aggregate capital stock is calculated by taking the sum of the stocks of the various types of assets. In contrast, we use the Törnqvist index for the aggregation (Equation 2.11).[13]

Figure 13 shows the FSO series (in growth rates) of the stock of capital and of capital services together with our own estimates. In the case of capital services, our estimates are shifted by one period to suppress the effects resulting from the fact that the FSO assumes $K_{i,t} = A_{i,t}$ whereas we assume $K_{i,t} = A_{i,t-1}$ (see "Timing" above). Figure 13 illustrates that the results presented in Section 5 differ little from those provided by the FSO, once it is taken into account that the FSO assumes that capital services of a given type of asset in period t are proportional to the asset stock at the end of period t, whereas we assume that they are proportional to the asset stock at the end of period $t-1$ (Equation 2.3).

[13]We thank Pierre Sollberger for kindly answering our questions about the FSO calculations of the net capital stock.

$K_{i,t} = A_{i,t-1}$ can be defended on the ground that capital goods have to be installed to generate services. This said, both $K_{i,t} = A_{i,t}$ and $K_{i,t} = A_{i,t-1}$ can be plausible in some situations and less so in others. On the one hand, when all investment is carried out at the beginning of the year, $K_{i,t} = A_{i,t}$ may give more appropriate results than $K_{i,t} = A_{i,t-1}$, even when we assume that it may take some time for new investment to provide productive services. On the other hand, when all investment is carried out at the end of the year, $K_{i,t} = A_{i,t-1}$ is clearly preferable to $K_{i,t} = A_{i,t}$. As argued in Section 6.5, it is realistic to assume that investment activity is spread evenly over the year and capital services are proportional to the asset stocks in the middle of the year. The methodological adjustments made necessary by this alternative assumption are described in Oulton and Srinivasan (2003) and BEA (2003). Results for Switzerland are presented in Section 6.5.

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