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Multi-factor productivity measurement: from data pitfalls to problem solving – the Swiss way

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1 Introduction

During the past 15 years, the Swiss economy faced sluggish growth and a rise of its unemployment rate. While still low compared to other countries the rise of unemployment triggered political discussions about the relative competitiveness of the Swiss economy. Much attention was then devoted to measurement issues of labor productivity. This focus on labor productivity partly resulted from a lack of data on capital stocks and multifactor productivity (MFP). Another factor was the lack of experience of countries like Switzerland regarding measurement issues and interpretation of results of capital stocks and MFP. In this context, the Organization for Co-operation and Development (OECD) was a key driver when it published two manuals[1] describing the concept and measurement of capital services and their relation to the measures of gross capital stock. The Swiss Federal Statistical Office (SFSO) relied of this new conceptual framework and started work on experimental series of capital stocks, capital services and MFP. The intent was twofold:

- have new information on the stock of capital assets which could be used in parallel to the stock of financial assets which the SFSO recently developed in cooperation with the Swiss National Bank (SNB);
- provide a new analytical framework where contributions of capital input and labor input could be associated with the evolution of MFP.

The work of the SFSO was constrained by three factors:

- First, no additional surveys could be carried out specifically for this field of study. Swiss enterprises have a feeling that the statistical burden is already high enough, and any new analytical output thus has to rely on existing data.
- Second, a central concern was the coherence with the central data framework of the Swiss National Accounts (N.A). By sticking to the central framework of N.A, international comparability should be guaranteed to a great extent.
- Third, work carried out in Switzerland ought to integrate conceptual developments carried out since the publication of the OCDE manuals in 2001. In particular, it should draw upon discussions on “best practices” for the rate of return and for the age-efficiency and age-price profiles of capital goods.

The conceptual framework of the OCDE was an invaluable help during the whole process. Work started in 2005 with the first estimate of the capital stock based on N.A inputs. The results had to be set in a more general context and some new questions like the choice of the depreciation profile became more prominent. Step by step the team in charge of the project worked its way through new concepts and measurement issues. The constraints mentioned above limited the spectrum of technical possibilities, but outcomes are sound and coherent with the central framework of N.A. Just before the OCDE workshop, the SFSO published a whole data set on contributions of capital and labor inputs to growth, and rates of change of MFP with various subcomponents, for the period 1991 to 2004.

This paper provides an overview of the concepts and methods underlying capital stock measures in Switzerland (Chapter 2), capital services (Chapter 3) and MPF profiles (Chapter 4). A final chapter discusses some of the consequences of the options chosen.

2 Capital stock measures

2.1 Definition

The capital stock encompasses all produced assets which are included in the production process. For analytical purposes, it is useful to define various kinds of assets.

Based on the System of National Accounts (SNA 1995), the typology of assets relies on two criteria. The first criterion is the distinction between produced and non-produced fixed assets[2]. A produced

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[1] OECD (2001a) and OECD (2001b).

[2] For further details, see SNA95, §10.6ss.

fixed asset is defined as a result of a production process. Thus, it is possible to differentiate for instance a building from an oil field. The second criterion is the tangibility of the fixed asset. For example, the tangible asset category contains aircrafts whereas computer software is assigned to the category of intangible assets.

Data availability in Switzerland was cross-checked on the basis of this pattern. The result was encouraging: data was available both on tangible fixed assets and on computer software. These various categories are certainly the most dynamic for an economy like Switzerland and represent approximately two thirds of the capital accounts of partner economies. Therefore, the existing information already covers a broad range of assets. A preliminary cost-benefit analysis indicated that additional information would be associated with a heavy burden on responders. Consequently no additional surveys were carried out. The capital stock of Switzerland therefore covers both tangible fixed assets and computer software. The various categories of assets covered in Switzerland are listed in Annex 1.

Before turning to the methodology used, a point must be made here: in Switzerland, gross fixed capital formations (GFCF) is based on a product-oriented approach. It thus provides no information regarding the industry or sector which is at the origin of the purchase. In other words, figures on GFCF in software represent the overall amount of purchased software of the Swiss economy. It gives no information on the amount spent for example by the software industry itself. This characteristic tends to preclude for the time being sector measures of capital stock.

2.2 Methodology

In accordance with the OECD 2001 manual, gross capital stock (GCS) is valued at “replacement cost”, that is according to current market prices for a new asset. It is then expressed at constant prices by using deflators based on year 2000.

There are several methods to calculate the GCS. The **perpetual inventory method** (PIM) was chosen for two main reasons. On the one hand, Switzerland currently has no official estimation for a capital stock. Thus, any construct has to rely on data of GFCF. In this context the PIM provides a reliable solution. On the other hand, many countries have successfully implemented this method. Its use in Switzerland would thus produce results which ought to be fully compatible from a methodological point of view with those of other OECD members.

The PIM method builds up a cumulative stock of assets from past investments. It can be expressed as follows:

$$GCS_t = \sum_{j=0}^{L} \mathbf{GFCF_{t-j} g_j} \qquad (1)$$

Where:

t is time (in year)

$GFCF_{t-j}$ is gross fixed capital formation in year t-j,

g_j is the part of gross fixed capital formation of a fixed year in activity after j years,

L is equal to 2 * lifetime (in year) of the fixed asset.

The part of gross fixed capital formation (g_j) which is still active after j years is calculated with <u>mortality</u> and <u>survival</u> functions. Various density functions can be used to estimate mortality functions. A bell-shaped distribution estimated by a log-normal density function was chosen in Switzerland, owing to the fact that this type of distribution function is commonly used in this field. Besides, only a very limited number of assumptions (in particular on the flatness of the distribution curve) have to be made to compute mortality curves. Thus, the density function reads as follows:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \frac{1}{x} \exp(-(\ln x - \mu)^2 / 2\sigma^2) \qquad (2)$$

where:

x = years 1, 2, …, L

σ = standard deviation computed as:

$$\sigma = \sqrt{\ln(1 + \frac{1}{(m/s)^2})} \quad (3)$$

µ = log-normal distribution mean computed as:

$$\mu = \ln(m) - 0.5\sigma^2 \quad (4)$$

m = estimated average lifetime of the fixed asset

s controls the flatness of the distribution curve. *s* is fixed between m/2 and m/4. Given the fact that no data was available in Switzerland in order to estimate the real curve of mortality function, a value of *s*=m/3 was arbitrarily chosen for every type of fixed assets[3].

Thus, the survival function can be expressed as:

$$g(x) = 1 - \int_{t-L}^{t} \frac{1}{\sigma\sqrt{2\pi}} \frac{1}{x} \exp(-(\ln x - \mu)^2 / 2\sigma^2) dx \quad (5)$$

where the amount of assets still in uses for the year t-i (i<L) corresponds to the GFCF made in year t-L minus the sum of all assets which were withdrawn from the process of production during the period [t-L ; t-i].

2.3 Time series and data availability

While there are numerous advantages to use the PIM, a main drawback is the issue of the length of time series. Actually, the PIM requires historical data for a period which is twice as long as the lifetime of the various fixed assets. This is linked to the fact that all assets of a given category are not discarded at the same time. For example, cars with an estimated lifetime of 10 years do not stop to be operational at the same time during their 10th year. Some cars are discarded earlier, some later. By doubling the lifetime taken into account, one can reasonably make the assumption that all assets are then discarded in the capital account.

In Switzerland, no surveys were ever made on lifetimes of assets. Thus, National accounts made estimates based on the experiences of various partner countries. Annex 1 gives lifetimes currently used in N.A in Switzerland. Annex 2 confronts the information needs in terms of time series with the data currently available in N.A. For some activities, the information is sufficient (software, industrial crops, etc.) while for others there is a lack of data. The most important deficit is for GFCF in construction[4], where data goes back to 1948 only while data is needed up to 1890. Consequently, a back-calculation based on a log linear regression model in first difference was implemented.

To back-calculate gross fixed capital formation in construction ($GFCF^{CONSTR}$) the assumption is made that there is a relationship between the evolution of Gross Domestic Product (GDP) and $GFCF^{CONSTR}$. This relation is sufficiently strong to express the $GFCF^{CONSTR}$ evolution with the evolution of GDP, adjusted with an elasticity rate[5].

Given that:

$$\Delta GDP_t = \frac{GDP_t - GDP_{t-1}}{GDP_{t-1}} \quad \text{and} \quad \Delta GFCF_t^{CONSTR} = \frac{GFCF_t^{CONSTR} - GFCF_{t-1}^{CONSTR}}{GFCF_{t-1}^{CONSTR}} \quad (6)$$

where:

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[3] The same criteria as those taken by the National Bank of Belgium (BNB, 2002) were chosen.

[4] An important point must be made here. In Switzerland, “Dwellings” and “Other buildings and structure” are included into the “Construction” category. This point thus differs from the OECD practice, but it is tolerated by the OECD manual « Measuring productivity ». The fact that this distinction is not made in Switzerland is linked to the unavailability of necessary data for back-calculation.

[5] In order to make this assumption, a correlation test between *$GFCF^{CONSTR}$* and *GDP* (ρ=.97) was implemented. Besides, an augmented Dickey-Fuller test (ADF) was also used to verify the stationary of GDP and $GFCF^{CONSTR}$ time series. Results reject for both time series the time-invariant hypothesis.

GDP_t = Gross domestic product for the year t.

$GFCF_t^{CONSTR}$ = Gross fixed capital formation in construction for the year t.

we can express our assumption as:

$$\Delta GFCF_t^{CONSTR} = \varepsilon_{GFCF}^{CONSTR} \Delta GDP_t \qquad (7)$$

where $\varepsilon_{GFCF}^{CONSTR}$ is the elasticity between GDP and $GFCF^{CONSTR}$ evolution.

$\varepsilon_{GFCF}^{CONSTR}$ can be estimated with a simple log linear regression model in first difference. Thus, the model is expressed as:

$$\log\left(\frac{GFCF_t^{CONSTR}}{GFCF_{t-1}^{CONSTR}}\right) = \hat{\beta}_0 + \hat{\beta}_1 \log\left(\frac{GDP_t}{GDP_{t-1}}\right) \qquad (8)$$

where

$$\hat{\beta}_1 = \hat{\varepsilon}_{GFCF}^{CONSTR} \qquad (9)$$

Table 1: Back-calculation of construction (Regression model results)

Variable	Coefficient	Std. dev.	t-statistics	P-value.
Constant	-0.022	0.008	-2.923	0.005
GDP	2.063	0.203	10.158	0.000

R^2= 0.674 F-statistic Prob. = 0.000

Model (8) is significant with a p-value < .00 and one gets $\hat{\varepsilon}_{GFCF}^{CONSTR} = 2.063$

With (7), (8) and (9) one can proceed to the back-calculation with:

$$GFCF_{t-1}^{CONSTR} = \frac{1}{1 + (\hat{\varepsilon}_{GFCF}^{CONSTR} * \Delta GDP_t)} GFCF_t^{CONSTR} \qquad (10)$$

Hence with (10), the official GFCF for construction can be back-calculated by applying the average evolution rate from the oldest available data of the official time series (that is to say 1948). Then, step by step, data is computed back up to 1890[6].

Back-calculation is also needed for a number of other fixed assets, as official data series often go back only to 1971. However the situation here is better than for investment in construction. As a matter of fact, before Swiss N.A revised their figures in 1997 due to the introduction of the European System of Accounts of 1978 (ESA 78), long time series had been set up in the pre-ESA 78 system. These series went back to 1948. These long time series are the only series available in Switzerland for back-calculation and, given the fact that there were only minor methodological changes for non financial assets linked to the implementation of ESA78, these series were used to construct the capital stock. Thus, for the period 1948-1970, the average evolution rates of the various fixed assets of the old time series are assumed to be equal to the average evolution rates of the fixed assets equipment goods of the official time series.

That is to say:

[6] Historical GDP time series come from Andrist, Anderson and Williams (2000).

$$GFCF_{i,t-1}^{EQUIP;OFF} = GFCF_{i,t}^{EQUIP;OFF} * \frac{1}{1 + \Delta GFCF_{i,t}^{EQUIP;OLD}} \quad (11)$$

where:

$GFCF_{i,t}^{EQUIP;OFF}$ = Total gross fixed capital formation for equipment goods i of the current official time series for year t.

$GFCF_{i,t}^{EQUIP;OLD}$ = Total gross fixed capital formation for equipment goods i of the pre ESA 78 time series for year t.

and

$$\Delta GFCF_{i,t}^{EQUIP;OLD} = \frac{GFCF_{i,t}^{EQUIP;OLD} - GFCF_{i,t-1}^{EQUIP;OLD}}{GFCF_{i,t-1}^{EQUIP;OLD}} \quad (12)$$

Thus with (11), official GFCF for equipment goods can be calculated by applying the average evolution rate of every type of fixed assets from the pre-ESA 78 data to the last available time series (that is to say 1971, see Annex 2). Then, step by step, data is computed back up to 1950 for the various types of assets.

2.4 Main findings

With the help of the PIM, the various types of fixed assets were aggregated and the Swiss capital stock was calculated for the period 1991 – 2004.

Table 2: Swiss capital stock, in million CHF, at constant prices (reference year: 2000)

Years	Agricultural assets	Equipment goods	Software	Construction	Total
1990	3'803	467'322	7'815	1'073'253	1'552'193
1991	3'813	483'306	8'020	1'109'223	1'604'361
1992	3'790	492'124	8'032	1'144'350	1'648'295
1993	3'757	498'342	7'973	1'178'547	1'688'619
1994	3'762	505'503	8'231	1'215'232	1'732'727
1995	3'735	517'018	8'877	1'249'725	1'779'354
1996	3'738	528'715	9'875	1'280'822	1'823'150
1997	3'708	541'025	11'407	1'310'698	1'866'838
1998	3'705	556'122	13'985	1'340'373	1'914'186
1999	3'676	572'026	17'095	1'367'929	1'960'725
2000	3'657	589'943	19'421	1'395'931	2'008'952
2001	3'658	604'667	21'582	1'421'917	2'051'824
2002	3'647	616'339	24'343	1'448'099	2'092'429
2003	3'591	625'439	26'291	1'474'344	2'129'665
2004	3'567	635'441	28'504	1'501'591	2'169'102

Table 2 shows that fixed assets in construction and equipment goods are by far the most dynamic part of the capital stock, construction[7] being the dominant asset (two thirds of the Swiss capital stock). Conversely agricultural assets are marginal with a relative part of 0.2% of total capital stock. Annex 3 gives more details for results by asset categories.

[7] As mentioned in footnote 4, construction figures include dwellings. Thus caution is needed when Swiss findings are compared with other countries results.

3 Capital services

3.1 Definition

The next step on the road to multi-factor productivity is the calculation of capital services. The stock cannot be used as such for the analysis of productivity. This is linked to the underlying assumptions of the stock. By construction, the stock is the sum of the flows of investments corrected by the removal of discarded capital goods. The implicit assumption is that an asset's productive capacity remains fully intact until the end of its service life (Schreyer and Pilat; 2001). In the real world, past vintages of capital goods are less efficient than new ones. Therefore, assumptions have to be made to convert the capital stock into these capital services.

Here, two options can be used. As mentioned in Schreyer, Diewert and Harrison (2005), there are two alternative ways of computing capital services. The first way is to start out with the choice of depreciation parameters and from there, to develop quantity measure of capital services by moving from age-price to age-efficiency function. The second way is to directly compute quantity of capital services with the help of an age-efficiency function.

In Switzerland, the second option was used with the implementation of an **age-efficiency function.** This function captures capital services of fixed assets, as it indicates the development of the productive capacity of assets over their service lives (OECD; 2005a). In other words, it captures the relative marginal productivity of two vintages of the same type of assets, and thus reflects the loss in productivity due to wear and tear and/or technical obsolescence (Schreyer, Bignon and Dupont; 2003). With the help of age-efficiency profile, assets of various vintages can be aggregated by transforming the latter into **standard efficiency units**. These concepts are further developed in the next chapter.

3.2 Methodology

3.2.1 Age-efficiency and age-price functions

Various kinds of age-efficiency functions are available. The SFSO chose a **double-declining truncated geometric function**[8] for three reasons: i) geometric functions are widely used by OECD member states, and Swiss results would thus be comparable to those of other countries; ii) geometric patterns are very convenient to use; iii) the geometric function takes into account the age-price profile and thus no further developments are needed to describe the relative price of different vintages of the same asset at a given point in time. In line with international recommendations, no explicit retirement function was formulated due to the fact that geometric functions capture both the effects of wear and tear and retirement.

With the help of the age-efficiency profile determining the efficiency decline, the productive stock of fixed asset i (S_i^t) can be expressed as:

$$S_t^i = \sum_{j=0}^{n} (1-\delta^i)^j \, GFCF_{t-j}^i \quad (13)$$

where δ^i is the anticipated rate of efficiency decline and $GFCF^i_{t-j}$ the quantity of investment in new assets of type i in year t-j[9].

3.2.2 User costs

The next issue to consider is the price of renting one unit of the productive stock for one period. If there were complete markets for capital services, rental prices could be directly observed. Some rental prices exist of course, but the most common case is that of capital goods which are owned and used by the same persons. In that case, rental prices have to be imputed. The implicit rent that capital good

[8] Function is truncated when efficiency rate is <.10.

[9] Implicitly we admit two important assumptions: 1) a perfect substitutability between different vintages, and 2) proportionality between the flow of capital services and the productive stock. Non respect of these two assumptions will not be discussed in this paper.

owners "pay" themselves gives rise to the terminology "user costs of capital". These costs are also needed to aggregate the different kinds of fixed assets. According to OECD (2001b) and Schreyer, Diewert and Harrison (2005), user costs ($u_0^{i,t}$) are estimated by:

$$u_o^{i,t} = P_o^{i,t}\left(r^{*t} + \delta_0 - \left(\Delta p^{i,t} - \omega^t\right)\right) \qquad (14)$$

where,

$u_o^{i,t}$ = user cost for the period t, of the fixed asset i; (2000=100);

$P_o^{i,t}$ = Price index of the fixed asset i (2000 = 100);

r^{*t} = net rate of return;

δ_0 = Depreciation rate (geometric, *double declining balance*[10]);

$\Delta p^{i,t}$ = price variation of the fixed asset i between periods t and t-1;

ω^t = Inflation rate of the Swiss economy for the period t;

$\left(\Delta p^{i,t} - \omega^t\right)$ represents a holding gain/loss.

The term in the largest bracket constitutes the gross rate of return that one franc invested in the purchase of capital good *i* must yield in a competitive market. The gross rate of return itself comprises three terms:

- A rate of depreciation (δ_0) which materializes the loss in market value of a capital good due to ageing.
- A revaluation term, or capital gain/loss term $\left(\Delta p^{i,t} - \omega^t\right)$. Here the price evolution of a given asset is benchmarked against the general evolution of prices as given by the Consumer price index (CPI). Because the revaluation term enters into the user cost expression with a negative sign, a fall in asset prices raises user costs, mirroring the fact that there is an opportunity cost which arises from the loss of value of a given asset. For example, rental prices for personal computers have to take into account the fall in market prices and the ensuing loss in value of the computers which are in use.
- A net rate of return which is the expected remaining remuneration for the capital owner once depreciation and asset price changes have been taken into account.

The choice of r is a matter of importance: the value of the user cost term determines the value of capital services of asset *i* as well as the overall remuneration of capital. This issue is dealt with in the next chapter while the question of holding gains and losses is treated in chapter 3.2.4.

3.2.2.1 Interest rate

Basically there are two major options for the rate of return r.

1. Set the rate of return so that the resulting value of capital services exactly exhausts the value of non-labor income (that is gross operating surplus) which is computed in N.A. This **endogenous** rate of return is thus fully consistent with the framework of the N.A. Its drawback is that it builds on a number of assumptions underpinning the underlying model which can be questioned. For example one assumes perfect competition, rational expectations of actors and constant rates of return. The fact that these assumptions do not meet with unanimous support tends to indicate that the endogenous rate of return is not the best option.

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[10] Even if double declining balance could be debatable (see Fraumeni, 1997), this method is widely used by other members of OECD.

2. Choose an external rate of return. A common option is to take market interest rates as a proxy. This **exogenous** rate of interest thus mirrors conditions on markets and has strong links with the financial framework in which firms operate. While no extra assumptions are needed here, the resulting values of capital services do not necessarily add up to gross operating surplus and this may complicate growth accounting exercises. Besides, an important drawback is the difficulty to find interest rates which incorporate a risk premium which is consistent with the rate of return approach. As a matter of fact, in Switzerland, long-time series of interest rates are available only for government bonds. These are considered as risk-free by most analysts and are thus not a good choice for the rate of return.

Calculations were nevertheless carried out in Switzerland for both options. For the period 1991-2004, the endogenous rate of return is 2.4% while the exogenous rate turns out to be 4.4%. These values can be considered as being the minimum and maximum for the estimate. In this context the SFSO decided to take an **average of both rates** as a proxy for the rate of return. The latter therefore is valued at 3.4% and held constant during the whole period. This treatment means that the rate of return is an ex-ante rate, which is coherent with the conceptual framework chosen here.

3.2.2.2 Holding gains/losses

As indicated above, holding gains tend to lower the user cost while holding losses raise that cost. A holding gain appears when the price of the underlying asset rises more than the general rate of inflation, and conversely for a capital loss. For the analysis, the difficulty arises when large price changes occur which may have a significant impact on the user cost. In some cases, the holding gain could be such that it compensates totally not only the acquisition price, but also the interest rate and the rate of depreciation. In such an extreme case, given the negative sign in front of the bracket term, the user cost would be negative, which is quite a challenging result for the analyst.

The possibility of having such a negative outcome cannot be readily discarded. To cope with such a situation, the following assumption is adopted: an investor will estimate an expected holding gain/loss in accordance with results of previous years. In order to reproduce the investor behavior, a simple linear regression model is used with as dependant variable the ex post holding gain/loss $\left(\Delta p^{i,t} - \omega^{t}\right)$ observed between 1980 and 2004 and time as independent variable. If the model shows a significant trend, fitted values are used in equation (14) to estimate the expected (*ex ante*) holding gain/loss. *A contrario*, if the result of the regression model is not significant, the mean of *ex post* holding gain/loss of the period 1980-2004 is computed and is applied for every year. In that way, this mean neutralizes the potential price volatility of asset categories. In both situations (that is, results of the linear regression model and results of the mean), the values obtained are held constant during the whole period 1991-2004. This *ex-ante* approach should avoid the possibility of having to cope with negative user costs in a specific year.

Table 3: Holding gains/losses: Results of simple linear regression model

Dependant variable	β1	p-value
Fabricated metal products	-0.006463	0.9799
Machinery and equipments	-0.039935	0.5376
Office machinery and computers	-0.422520	0.0004**
Electrical machinery and apparatus	-0.096855	0.2126
Radio, television and comm. equip. and apparatus	-0.280197	0.0009**
Medical, precision and optical instruments, watches	-0.129231	0.1190
Motor vehicles, trailers and semi-trailers	-0.056233	0.3769
Other transport equipment	0.057169	0.5986
Construction	0.006671	0.9288
Informatics	-0.235699	0.0497*

*: significant at 95%-level ; **: significant at 99%-level

3.3 Capital services index

Once standard efficiency units and user costs are computed, it is possible to calculate the overall capital services index. Cost shares are important in this context, as they are used as weights to aggregate services from the different types of assets. Given the fact that user costs shares reflect the relative marginal productivity of the different assets, these weights provide a means to effectively incorporate differences in the productive contribution of heterogeneous investments into the overall measure of capital input. The theoretically recommended index is the Törnqvist index which applies average users cost weights to each asset's rate of change in capital services. The index is computed by:

$$\ln\left(\frac{S_t}{S_{t-1}}\right) = \sum_i \tfrac{1}{2}\left[\frac{u_t^i S_t^i}{\sum_i u_t^i S_t^i} + \frac{u_{t-1}^i S_{t-1}^i}{\sum_i u_{t-1}^i S_{t-1}^i}\right]\ln\left(\frac{S_t^i}{S_{t-1}^i}\right) \qquad (15)$$

Where,

S_t^i = amount of capital service of fixed asset i at year t, and $S_t = \sum_i S_t^i$ u_t^i= user cost of fixed asset i at year t,

4 Multi-factor Productivity

Numerous papers of research have already discussed the theoretical framework of multi-factor productivity (MFP) (for instance: Schreyer, 2001; OECD, 2001b). Here supplementary information is provided on inputs used, which in turn are based on the methodology applied in the OECD Compendium of productivity indicators (OECD, 2005b).

4.1 Methodology

Output is measured as GDP at constant prices[11] for the entire Swiss economy. Year-to-year change is given by

$$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right)$$

[11] At prices of preceding year, base year = 2000.

Labor input is measured as total hours actually worked in the entire economy. Year-to-year change is given by $\ln\left(\frac{L_t}{L_{t-1}}\right)$.

To measure the **remuneration of labor** input, the average remuneration per employee is multiplied by the total number of persons employed. This adjustment is needed in order to include self-employed persons whose income is logically not a part of the compensation of employees (OECD, 2005b).

Thus, the remuneration of labor input is expressed as:

$$w_t L_t = \left(\frac{COMP_t}{EE_t}\right) E_t \qquad (16)$$

Where,

$w_t L_t$ = Total remuneration of labor input (employees + self-employed) in period t ;

$COMP_t$ = Compensation of employees for period t;

EE_t = Number of employees in period t ;

E_t = Total number employed (employees + self-employed) in period t.

No information is available in Switzerland about E_t, for a whole year. As a proxy, the split of E_t between EE_t and self-employed persons is used. This split is only available for the middle of the second semester of a given year. An assumption is therefore made that the relative part of self-employed persons at the middle of the second semester for year t is equal to the average relative part of self-employed persons for the year t.

Data on remuneration of employees are computed by national accounts[12] and employment statistics (ES) are provided by the Swiss labor force survey (SFSO, 2004).

Using the same methodology (OECD, 2005b), the rate of change of **total inputs** is computed as a weighted average of the rate of change of labor and capital input. The weights of each input are their respective shares in total cost of inputs[13]. Here again, a Törnqvist index is used to evaluate the rate of change:

$$\ln\left(\frac{X_t}{X_{t-1}}\right) = \tfrac{1}{2}(s_t^L + s_{t-1}^L)\ln\left(\frac{L_t}{L_{t-1}}\right) + \tfrac{1}{2}(s_t^S + s_{t-1}^S)\ln\left(\frac{S_t}{S_{t-1}}\right) \qquad (17)$$

Where share of labor input in costs is estimate by:

$$s_t^L = \frac{w_t L_t}{w_t L_t + \sum_i u_t^i S_t^i} \qquad (18)$$

and share of capital input in costs is given by:

$$s_t^S = \frac{\sum_i u_t^i S_t^i}{w_t L_t + \sum_i u_t^i S_t^i} \qquad (19)$$

4.2 MFP estimation

MFP is measured as the difference between output and input contributions.

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[12] Data are available in SFSO (2005).

[13] Total cost of inputs is given by: $\mathbf{C_t = w_t L_t + \sum_i u_t^i S_t^i}$.

$$\ln\left(\frac{PMF_t}{PMF_{t-1}}\right) = \ln\left(\frac{GDP_t}{GDP_{t-1}}\right) - \ln\left(\frac{X_t}{X_{t-1}}\right) \quad (20)$$

A measure of MFP of the Swiss economy can therefore be calculated for the period 1992-2004:

Table 4: Evolution of the MFP of the Swiss economy

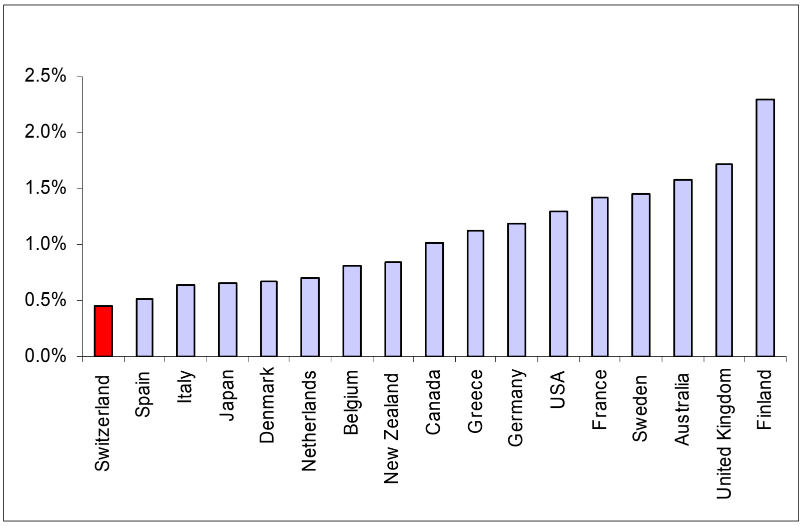
Years	MFP
1992	0.2%
1993	0.2%
1994	0.1%
1995	0.5%
1996	1.0%
1997	1.6%
1998	0.5%
1999	-1.1%
2000	2.2%
2001	0.9%
2002	0.1%
2003	-0.8%
2004	0.3%
1991-1996	0.4%
1996-2000	0.8%
2000-2003	0.1%
1991-2004	0.4%

Further details are available in the annex 4.

4.3 International Comparison of MF*P*

Before turning to the international comparison, a point made before can be reiterated here. Although the methodology used in this document is compatible with international practice, there are small differences with the OECD practice for estimating capital services. The OECD excludes dwellings from its estimates while this exclusion is not made in Switzerland due to the unavailability of data for the back-calculation model. This being said, the results for Switzerland are benchmarked with data of other members of OECD in Figure 1, which compares growth rates of MFP:

Figure 1: International Comparisons of MFP (1991 – 2003)[1]



Source: SFSO and OECD *Productivity database*

1. 1991 – 2002 for Australia, Japan and New Zealand

In comparison with other OECD members, the evolution of MFP for Switzerland is obviously quite weak (0.5% for Switzerland versus 1.1% on average for the whole OECD members). This is particularly true for the period 1991-1996 when the Swiss economy had a really weak growth rate with 0.4% versus 1.1% for OECD. During the period 1996-2000, the situation does not improve with an annual average growth rate of 0.5%, whereas the international annual average growth rate is 1.0%. Thus, for the whole analyzed period, Swiss economy has the weakest annual growth rate of MFP in international comparison.

5 Conclusion

This paper illustrated the various steps which were implemented by the SFSO to provide first estimates of the capital stock and of multifactor productivity. It shows that while the statistical database is not optimal, the conceptual framework of the OECD can be implemented to a great extent in Switzerland. It is worthwhile to mention that the results were cross-checked by the OECD and can thus be compared to those of other countries without reservation. The outcome is a very valuable input for further analytical work and for the evaluation of the overall situation of the Swiss economy.

This being said, a number of interesting features emerged from the production process as such. The SFSO can now identify and make a hierarchy of open points which should be analyzed in the future. Issues like lifetimes of assets and sector allocation have gained in importance, and must be studied in the medium term, taking into account the specific features of the Swiss economy. Besides, these open points may have a backlash on assumptions used by N.A in areas like depreciation. The forthcoming revision of N.A will be a precious opportunity to review some of the assumptions made in the past. Finally, the new figures must at one point be reconciled with an emerging feeling that the Swiss economy has been successfully restructured in the last 13 years. Some qualitative indicators tend to show that the Swiss economy is very competitive. The World Economic Forum just released its global competitiveness report which ranks Switzerland as being the most performing economy in the world for the first time ever[14]. As one can see, a lot of analytical work still lay ahead, but the new figures are a big step forward to critically assess the situation of the Swiss economy.

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[14] http://www.weforum.org/en/initiatives/gcp/Global%20Competitiveness%20Report/index.htm

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Annexes

Annex 1: Fixed assets and lifetimes

Assets	Lifetime (years)
Fruits	8
Hops	20
Industrial crops	12
Arboriculture	15
Vineyards	25
Animals	-[15]
Fabricated metal products	18
Machinery and equipments	18
Office machinery and computers	7
Electricity distribution and control apparatus	15
Radio, television and comm. equip. and apparatus	15
Medical, precision and optical instruments, watches	15
Motor vehicles, trailers and semi-trailers	10
Other transport equipment	20
Construction	50
Software	4

Annex 2: Availability of time series

Assets	GFCF needed since:	GFCF available since:
Fruits	1974	1940
Hops	1950	1940
Industrial crops	1966	1940
Arboriculture	1960	1940
Vineyards	1940	1940
Fabricated metal products	1954	1971
Machinery and equipments	1954	1971
Office machinery and computers	1976	1971
Electrical machinery and apparatus	1960	1971
Radio, television and comm. equip. and apparatus	1960	1971
Medical, precision and optical instruments, watches	1960	1971
Motor vehicles, trailers and semi-trailers	1970	1971
Other transport equipment	1950	1971
Construction	1890	1948
Software	1982	1971

GFCF = Gross fixed capital formation

[15] Animal stock estimation is based on livestock.

Annex 3: Swiss capital stock, 1990-2004

In million CHF, at constant price (reference year: 2000)

Years	Agricultural assets	Equipment goods*										Construction	Total
		E1	E2	E3	E4	E5	E6	E7	E8	E9	Total E.		
1990	3'803	345	275'268	11'968	49'736	30'228	46'382	15'080	38'314	7'815	475'137	1'073'253	1'552'193
1991	3'813	352	282'671	12'396	51'448	31'342	47'988	15'548	41'560	8'020	491'326	1'109'223	1'604'361
1992	3'790	362	286'970	12'684	52'611	31'993	49'251	15'820	42'432	8'032	500'156	1'144'350	1'648'295
1993	3'757	370	290'013	12'953	53'734	32'542	50'439	15'805	42'487	7'973	506'315	1'178'547	1'688'619
1994	3'762	378	293'141	13'490	55'069	33'175	51'823	15'983	42'443	8'231	513'733	1'215'232	1'732'727
1995	3'735	384	299'028	14'247	56'124	33'661	53'212	16'174	44'187	8'877	525'894	1'249'725	1'779'354
1996	3'738	392	304'586	15'197	57'074	34'239	54'520	16'326	46'381	9'875	538'590	1'280'822	1'823'150
1997	3'708	398	309'209	16'595	58'327	35'235	56'131	16'386	48'743	11'407	552'432	1'310'698	1'866'838
1998	3'705	386	316'271	17'741	59'179	36'247	58'697	16'684	50'918	13'985	570'108	1'340'373	1'914'186
1999	3'676	406	321'478	19'211	60'075	37'421	61'652	17'161	54'621	17'095	589'120	1'367'929	1'960'725
2000	3'657	400	327'864	21'085	61'270	38'934	65'173	17'809	57'408	19'421	609'364	1'395'931	2'008'952
2001	3'658	397	332'294	22'627	62'580	39'659	69'337	18'511	59'263	21'582	626'250	1'421'917	2'051'824
2002	3'647	414	336'617	23'736	63'147	40'412	73'295	18'945	59'774	24'343	640'682	1'448'099	2'092'429
2003	3'591	430	339'822	24'652	62'705	41'438	76'337	19'356	60'699	26'291	651'730	1'474'344	2'129'665
2004	3'567	441	344'296	25'894	62'162	43'061	78'484	19'790	61'312	28'504	663'944	1'501'591	2'169'102

*E1: Fabricated metal products; E2: Machinery and equipments; E3: Office machinery and computers; E4: Electrical machinery and apparatus; E5: Radio, TV and comm. Equipment and apparatus; E6: Medical, precision and optical instruments, watches; E7: Motor vehicles, trailers and semi-trailers; E8: Other transport equipment; E9: Software.

Annex 4: Swiss MFP and its components, 1992-2004

Years	GDP at constant prices	Labor input	Labor productivity	Cost share of labor input	Contribution of labor input	Capital input	Capital productivity	Cost share of capital input	Contribution of capital input	Capital intensity	Contribution of capital intensity	Multi-factor productivity
	(1)	(2)	(3) = (1) - (2)	(4)	(5) = (2) * (4)	(6)	(7) = (1) - (6)	(8)	(9) = (6) * (8)	(10) = (6) - (2)	(11) = (8) * (10)	(12) = (1) - (5) - (9)
1992	0.0%	-0.9%	1.0%	69.1%	-0.6%	1.5%	-1.5%	30.9%	0.5%	2.4%	0.7%	0.2%
1993	-0.2%	-1.0%	0.8%	69.6%	-0.7%	1.1%	-1.3%	30.4%	0.3%	2.1%	0.7%	0.2%
1994	1.1%	0.6%	0.5%	69.9%	0.4%	2.0%	-0.9%	30.1%	0.6%	1.4%	0.4%	0.1%
1995	0.4%	-1.3%	1.7%	70.4%	-0.9%	2.6%	-2.2%	29.6%	0.8%	3.8%	1.1%	0.5%
1996	0.5%	-1.6%	2.2%	70.9%	-1.2%	2.3%	-1.8%	29.1%	0.7%	4.0%	1.2%	1.0%
1997	1.9%	-0.7%	2.6%	71.2%	-0.5%	2.6%	-0.7%	28.8%	0.7%	3.3%	0.9%	1.6%
1998	2.8%	1.8%	1.0%	71.3%	1.3%	3.3%	-0.5%	28.7%	0.9%	1.5%	0.4%	0.5%
1999	1.3%	2.1%	-0.8%	71.1%	1.5%	3.1%	-1.8%	28.9%	0.9%	1.0%	0.3%	-1.1%
2000	3.5%	0.7%	2.8%	70.7%	0.5%	2.8%	0.7%	29.3%	0.8%	2.1%	0.6%	2.2%
2001	1.0%	-0.7%	1.7%	70.5%	-0.5%	2.1%	-1.1%	29.5%	0.6%	2.9%	0.8%	0.9%
2002	0.3%	-0.6%	0.9%	70.7%	-0.4%	2.1%	-1.8%	29.3%	0.6%	2.6%	0.8%	0.1%
2003	-0.2%	0.4%	-0.6%	70.9%	0.3%	1.1%	-1.3%	29.1%	0.3%	0.7%	0.2%	-0.8%
2004	2.3%	2.1%	0.2%	70.6%	1.5%	1.6%	0.6%	29.4%	0.5%	-0.5%	-0.1%	0.3%
1991-1996	0.4%	-0.9%	1.2%		-0.6%	1.9%	-1.6%		0.6%	2.7%	0.8%	0.4%
1996-2000	2.4%	1.0%	1.4%		0.7%	2.9%	-0.6%		0.8%	1.9%	0.6%	0.8%
2000-2003	0.4%	-0.3%	0.7%		-0.2%	1.8%	-1.4%		0.5%	2.0%	0.6%	0.1%
1991-2004	1.1%	0.1%	1.1%		0.0%	2.1%	-1.0%		0.6%	2.1%	0.6%	0.4%