On Understanding Sources of Growth and Output Gaps for Switzerland

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by

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Abstract

In this paper, we measure the main factors explaining nominal output growth and deviations from trend output in Switzerland over the period 1980 to 2001. The decompositions are based on the GDP function and its dual, the national income function. The results indicate that whereas nominal output growth frequently reflects movements in domestic prices, it is capital formation that makes the largest contribution to real output growth, followed by gains in total factor productivity and improvements in the terms of trade. Deviations of real output from trend appear to have been driven by deviations of labour utilization, of productivity and, during the first decade, of the terms of trade from their respective long-run trends. The important role attributed to productivity and the terms of trade support the view that the customary measures of the output gap should be used with caution when formulating monetary policy.

Key words: GDP growth, output gap, index numbers, welfare.
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1 Introduction

The performance of the Swiss economy over the last three decades has been mixed. Whereas inflation was lower than in most other countries, economic growth was rather weak. Growth was especially poor during the 1990s when the Swiss economy stagnated for a number of years (1991-1996) and growth differentials vis-à-vis the euro area or the United States widened significantly (Prescott, 2002; Kehoe and Ruhl, 2003). Among the reasons put forward to explain the stagnation period are the fight against inflation made necessary by the monetary mishaps of the late 1980s, the collapse of the housing market at the beginning of the 1990s, the German recession of 1993-1994, the growing tax burden and the large expansion of the public sector in general (Kohli, 2002, p. 9). In addition, the surge of the Swiss franc and the stifling effect of overregulated product markets have sometimes been blamed. After the rejection of the European Economic Area Agreement in a popular vote in 1992, the federal government launched reforms to increase domestic competition and enhance the integration of the economy into the world economy. However, the pace of reform has been described as slow by many and the results of the effort are patchy (see OECD, 2006).

In this paper, we examine the macroeconomic performance of the Swiss economy over the period 1980-2001 based on an index number approach. In contrast to conventional applications of growth accounting, the starting point is nominal rather than real output. In addition, the analysis is not restricted to a single output and therefore allows the assessment of terms-of-trade effects. Drawing on the pioneering work of Diewert and Morrison (1986) and Kohli (1990, 2003c), we undertake two forms of growth decomposition. The first is based on the GDP function approach to modelling the production sector of an open economy. This decomposition emphasizes the role of quantities of factor inputs, technology, and prices of goods. The second focuses on the dual price and quantity variables. It is based on the National Income function and emphasizes the factor rental prices, technology, and the demand for goods. Both decompositions are exact and complete for the translog form of the respective functions.

Another way of looking at the data is to start from the output gap and to decompose this gap into its various contributing factors. The output gap is defined as the difference between actual and potential output, where the latter is approximated in this paper by a type of locally weighted regression smoothing. Following Fox and Warren (2001), we decompose the nominal output gap over the period 1980-2001 into the components of the GDP function and the National Income function. In other words, the trend deviation of actual GDP (or income) from trend is decomposed into the contributions coming from the deviations of the various components from their respective trends. This provides a complementary view of the macroeconomic performance of the Swiss economy, a view that focuses on the cyclical pattern of the data.

The purpose of this paper is to bring together a number of decomposition schemes and to apply them to a single data set. In a series of articles, Kohli (1993, 2002, 2003a, 2003c) has applied some of the same methods to Swiss data. However, these applications differ across articles with respect to the source of the data, the definition of the variables, and the time period considered. Therefore, the examination of Switzerland's macroeconomic performance we attempt in this paper is more closely related to what Fox, Kohli and Warren (2002, 2003) have done for New Zealand.

The paper is organized as follows. The next section describes the analytical framework to decompose output growth and the output gap into their contributing components. Section 3 describes the data and the calculation of the output gap. The results for the various growth and gap decompositions are given in section 4 and section 5, respectively. Section 6 provides a summary and presents some concluding remarks.

2 General Analytical Framework

We assume a model economy with N_d domestic (nontraded) goods, N_x export goods, and N_m imported goods. Therefore, we have $N = N_d + N_x + N_m$ net outputs, or "netputs", denoted by $y \equiv (y_1, \ldots, y_N)^T$, where a T superscript denotes the transpose operator. If $y_n > 0$ (< 0), then the n^{th} netput is an output (input). The price vector that corresponds to the net output vector y is $p \equiv (p_1, \ldots, p_N)^T \gg 0_N$.[1] Hence, using the notation $p \cdot y = \sum p_n y_n$, nominal GDP can be written as $\pi = p \cdot y$.

Suppose we have two observations on the GDP of a country, π^a and π^b. The ratio of these two observations is

$$\Gamma^{a,b} \equiv \pi^b/\pi^a = (p^b \cdot y^b)/(p^a \cdot y^a), \tag{1}$$

where p^i and y^i denote price and quantity vectors for states $i = a, b$. Dividing this value ratio by the price index for the netputs between a and b, $P^{a,b}$, gives us an "implicit netput quantity index" (Allen and Diewert, 1981) denoted by $Q^{a,b}$:

$$Q^{a,b} \equiv \Gamma^{a,b}/P^{a,b}. \tag{2}$$

To introduce production into the analysis, we assume that the production of the N netputs involves M primary inputs. The vector of primary input quantities is denoted by

[1] The notation $p \gg 0_N$ means each component of p is positive.

$v \equiv (v_1, \ldots, v_M)^T \geq 0_M$, and the corresponding price vector is $w \equiv (w_1, \ldots, w_M)^T \gg 0_M$. Let $V^{a,b}$ be the primary-input quantity index, between states a and b. A total-factor-productivity index can then be defined as

$$R^{a,b} \equiv Q^{a,b}/V^{a,b}. \tag{3}$$

By substituting (2) into (3), we obtain

$$\Gamma^{a,b} = R^{a,b} \cdot P^{a,b} \cdot V^{a,b}. \tag{4}$$

Thus the ratio of GDP observations in (1) can be decomposed into contributions from ratios of productivity ($R^{a,b}$), prices ($P^{a,b}$) and primary inputs ($V^{a,b}$).

If a and b represent time periods, this is a relatively simple growth accounting exercise. However, we can get a richer decomposition of nominal GDP growth if we assume a particular form for the indexes in (4). In this paper, we define $P^{a,b}$ and $V^{a,b}$ in (4) as Törnqvist (1936) indexes

$$P^{a,b} \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^a + s_n^b)\ln(p_n^b/p_n^a)\right], \tag{5}$$

and

$$V^{a,b} \equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}(s_m^a + s_m^b)\ln(v_m^b/v_m^a)\right], \tag{6}$$

where $s_n = (p_n y_n)/(p \cdot y)$ denotes the share of netput n in GDP, and $s_m = (w_m v_m)/(w \cdot v)$ is the income share of primary input m. Exploiting the weighted-geometric mean form of the Törnqvist-index formula, we can decompose the aggregate price index (5) into a product of individual price differences,

$$P^{a,b} = \prod_{n=1}^{N} P_n^{a,b}, \tag{7}$$

where $P_n^{a,b}$ is the Törnqvist price index in (5) calculated for the n^{th} netput. Similarly, the primary-input index (6) can be decomposed according to

$$V^{a,b} = \prod_{m=1}^{M} V_m^{a,b}, \tag{8}$$

where $V_m^{a,b}$ is the Törnqvist quantity index calculated for the m^{th} primary input.

Substitution of (7) and (8) into (4) then yields a detailed decomposition of the ratio of π^a to π^b:

$$\Gamma^{a,b} = R^{a,b} \cdot \prod_{n=1}^{N} P_n^{a,b} \cdot \prod_{m=1}^{M} V_m^{a,b}. \tag{9}$$

Justifications for the use of the Törnqvist index in aggregating over goods can be derived from the axiomatic and economic approaches to index-number theory.[2] Moreover, its use can be justified by practical reasons, because it allows us to perform decompositions as in (9). In an important contribution, Diewert and Morrison (1986) demonstrated a relationship between the translog functional form and the Törnqvist index formula, which they proposed for decomposing the growth in domestic product for a trading economy. Specifically, they considered the case where $a = t-1$ and $b = t$, with $t = 1, \ldots, T$ indexing time. In this formulation, the GDP ratio in (1) is an index of GDP growth between periods $t-1$ and t. Diewert and Morrison showed that if the GDP function is translog and there is competitive, profit-maximising behaviour, then the productivity index is a Törnqvist implicit output-quantity index divided by the primary-input-quantity index:

$$R^{t-1,t} = (\Gamma^{t-1,t}/P^{t-1,t})/V^{t-1,t}, \tag{10}$$

where $\Gamma^{t-1,t}$ is defined as in (1), and $P^{t-1,t}$ and $V^{t-1,t}$ are defined as in (5) and (6), respectively. Equation (10) can then be rearranged as in (4) to give a decomposition of the growth in GDP.[3]

With some modifications, the same basic framework can be used for decomposing the output gap (Fox and Warren, 2001). Let a and b in (1) be potential GDP and actual GDP, such that $\Gamma^{a,b}$ is the ratio of actual GDP to potential GDP, or a ratio measure of the output gap. The productivity index can then be written as

$$R^{t} = (\Gamma^{t}/P^{t})/V^{t}, \tag{11}$$

where Γ^t is defined as in (1), and P^t and V^t are defined as in (5) and (6). In contrast to the decomposition of output growth, Γ^t, P^t and V^t are now indexes for comparing values in the same period t rather than across periods. Equation (11) can be rearranged as in (4) to give a decomposition of the GDP gap.

There are further ways to extend the basic framework. One possibility is to play on the dual price and quantity variables. Using (2) and (3), the calculation of productivity growth and the productivity gap is based on an implicit output index and a direct input index. Alternatively, we can define a productivity index ($\mathcal{R}^{a,b}$) which is based on a direct output index and an implicit input index:

$$\mathcal{R}^{a,b} \equiv \mathcal{Y}^{a,b}/(\mathcal{C}^{a,b}/\mathcal{W}^{a,b}), \tag{12}$$

[2] Theil (1967) provided another justification for the Törnqvist index using the stochastic approach to index numbers.

[3] For further details of the GDP approach, see Kohli (1990, 1991) and Fox and Kohli (1998).

where

$$\mathcal{Y}^{a,b} \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^a + s_n^b)\ln(y_n^b/y_n^a)\right] \tag{13}$$

and

$$\mathcal{W}^{a,b} \equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}(s_m^a + s_m^b)\ln(w_m^b/w_m^a)\right] \tag{14}$$

are Törnqvist quantity indexes, and $\mathcal{C}^{a,b} = w^b \cdot v^b / w^a \cdot v^a$ is the ratio of "costs", or income to primary factors of production, between a and b. By rearranging (12), we obtain

$$\mathcal{C}^{a,b} = (1/\mathcal{R}^{a,b}) \cdot \mathcal{Y}^{a,b} \cdot \mathcal{W}^{a,b}. \tag{15}$$

It is straightforward to write down the growth and gap versions of (12) corresponding to (10) and (11), and to rearrange these equations according to (15). As this is a decomposition of the income to the factors of production, we refer to this as the "national income approach".[4]

3 Data

The framework presented in the previous section will be used in Section (4) to analyze the determinants of growth and output gaps in Switzerland. For this purpose, we require price and quantity series on all primary inputs (labour and capital), on imports and exports, and on domestic expenditures (i.e., the total of private consumption, private investment and government purchases).

The observation period is 1980 to 2001 and all data are annual. Data on the prices and quantities of GDP and its components have been obtained from the Swiss Federal Statistical Office. Data on the compensation of employees and the operating surplus are from the same source. No official series exist, however, for the quantities of labour and capital. Therefore, we have taken Swiss National Bank estimates for total hours worked and for the capital stock, where the latter is calculated with the perpetual inventory method based on starting values adapted from Goldsmith (1981).[5] The quantity of capital services is assumed to be proportional to the capital stock. The rental price of capital is calculated by dividing capital income by the capital stock series. Likewise the price of labour is calculated by dividing labour income by the the total of hours worked. All the price and quantity data are plotted in Figures 1 and 2.

[4]The methods in this section, with an appropriate change in interpretation, could be applied to the case of decomposing the profits and costs of firms, respectively.

[5]Details of the calculation are available from the authors on request.

The calculation of the output gap requires an estimate for potential output. This is regularly done by applying some kind of smoothing technique to generate a long-run trend.[6] A well known example is the Hodrick-Prescott (1997) filter, which is a cubic smoothing spline with the smoothing parameter (λ) restricted to take a specified value *a priori* (such as 1600). Some concerns have been raised about the appropriateness of the Hodrick-Prescott filter for estimating potential output (King and Rebelo, 1993; Harvey and Jaeger, 1993). In addition, other smoothing techniques incorporating data-dependent methods for estimating the appropriate degree of smoothness have been developed as improvements over the cubic smoothing spline.[7] Therefore, long-run trends are generated in this paper by applying the flexible Super Smoother technique (Friedman, 1984) to the original series. A description of the technique is given in the Appendix. Consistent with our model of production, the smoothing is performed at the component level. The resulting smoothed price and quantity data are represented by the solid lines in Figures 1 and 2.

4 Decomposition of GDP Growth

4.1 The GDP Function Approach

In this section, we use the index-number decomposition method of Diewert and Morrison (1986), as extended by Kohli (1990), to decompose nominal GDP growth into its main sources. From (10), and (7) and (8), we obtain

$$\Gamma^{t-1,t} = R^{t-1,t} \cdot A^{t-1,t} \cdot P_E^{t-1,t} \cdot V_L^{t-1,t} \cdot V_K^{t-1,t}, \tag{16}$$

where

$$A^{t-1,t} = \exp\left[\frac{1}{2}(s_M^{t-1} + s_M^t)\ln(p_M^t/p_M^{t-1}) + \frac{1}{2}(s_X^{t-1} + s_X^t)\ln(p_X^t/p_X^{t-1})\right] \tag{17}$$

is a Törnqvist index of the contribution of changes in the terms of trade to GDP growth. Hence, nominal GDP growth is decomposed into the contributions from changes in total factor productivity (TFP) ($R^{t-1,t}$), changes in the terms of trade ($A^{t-1,t}$), changes in domestic prices ($P_E^{t-1,t}$), changes in labour input ($V_L^{t-1,t}$), and changes in capital input ($V_K^{t-1,t}$), all in

[6] Various alternative methods are proposed in the literature. See Dupasquier, Guay and Saint-Amant (1999) for a survey. Gerlach and Yiu (2004) provide a comparison of methods applied to data for a number of Asian countries, and Gerlach and Smets (1999) provide estimates of the output gap for the EMU area.

[7] These techniques are now standard in most good statistical packages (e.g., S-PLUS, SAS, SPSS, and GAUSS).

index form.[8]

Before turning to the results, it may be useful to recall two caveats about growth accounting. The first relates to the fact that TFP growth tends to be pro-cyclical. Whereas this pattern is consistent with an interpretation of the business cycle as being driven by technology shocks, other explanations are often more natural. In particular, the short-term movements in TFP growth may simply reflect unconsidered pro-cyclical patterns in the utilization of labour and capital. The second caveat refers to the observation that the labour share of income tends to be counter-cyclical. This tendency may be caused by labour adjustment costs, and does not necessarily point to changes in the elasticities of output with respect to factor inputs. Both qualifications suggest that averages over complete business cycles (or at least over several years) are more reliable than results for individual years. Nevertheless, results for individual years may still be of interest and we will display them in our tables.

The results for the decomposition of nominal GDP (NGDP) growth based on (16) are presented in Table 1. Multiplication of the contributions of the five components (in index form) gives nominal GDP growth (in index form). Subtracting one and multiplying by one hundred yields results in percentage form. In addition to the variables from (16), the table shows the results for growth in real net output defined as nominal GDP growth net of changes in domestic prices, $\Gamma^{t-1,t}/P_E^{t-1,t}$. This definition of output implies that we treat changes in the terms of trade as a real effect. As Diewert and Morrison (1986) have pointed out, changes in the terms of trade have the same effect on real welfare as a change in productivity and should be treated accordingly.

The results indicate that nominal growth in GDP was 4.1% on average over the period 1981 to 2001. Rising domestic prices accounted for about half of nominal GDP growth (2.1%) so that the other half can be attributed to the increase in real net output (1.9%). The most important factor contributing to the growth in real net output was capital formation (1.0%) followed by growth in TFP (0.4%) and improvements in the terms of trade (0.3%). The contribution of growth in the quantity of labour was negligible (0.2%).

After splitting the sample into two periods of roughly equal length, we can see that both nominal GDP and real net output growth declined in the period 1992-2001 compared with the period 1981-1991. The slowdown in nominal growth (from 5.9% to 2.1%) was primarily caused by a fall in the contribution from domestic prices (from 3.4% to 0.8%), reflecting a significant decline in domestic price inflation in the 1990s. The slowdown in real growth

[8]This growth accounting approach was applied by Fox and Kohli (1998) to Australian data, and by Diewert and Lawrence (1999) and Fox, Kohli and Warren (2002, 2003) to New Zealand data.

(from 2.4% to 1.3%) was less marked but still substantial. It is accounted for in roughly equal measures by decreases in the contributions of changes in labour (from 0.4% to -0.1%), capital (from 1.2% to 0.8%), and the terms of trade (from 0.5% to 0.1%). Growth in TFP, however, increased slightly (from 0.3% to 0.5%).

Furthermore, Table 1 indicates that the contributions of the various growth components sometimes vary greatly from one year to the next. For example, in 1986 real net output growth was 5%, with positive contributions from labour (0.08%), capital (1.1%), but mainly from the terms of trade (3.1%), whereas TFP growth provided a slight drag (-0.1%) on growth. In the previous year the roles were the reverse, with productivity contributing strongly (1.2%) and the terms of trade being the source of a slight drag (-0.7%) on real growth of 2.7%.

In Figure 3, the contributions to real net output growth are shown in cumulative form. The bottom dashed line represents the contribution of labour input. To this is added capital, with the gap between the first two lines giving the cumulative contribution of capital beyond that of labour. The gap between the second and the third line reflects the cumulative contribution of the terms of trade, which initially provides a drag on growth, before adding to the contributions of labour and capital. Finally, the solid line represents the path of real net output, where the gap between this and the previous line represents the contribution of productivity growth. Note that initially TFP drags down real growth, before providing an overall positive contribution exceeding that of the terms of trade by the end of the sample.[9]

Before proceeding further, we have to discuss whether the interpretation of $A^{t-1,t}$ as a terms-of-trade-effect is adequate. A potential problem with this interpretation is that $A^{t-1,t}$ is not homogeneous of degree zero in prices. This means that a proportional increase in export and import prices will lead to a change in $A^{t-1,t}$, unless trade is balanced. The issue then is how to split up $P^{t-1,t}$ in (16), if $P^{t-1,t} = P_E^{t-1,t} \cdot A^{t-1,t}$ is not deemed as appropriate.

Kohli (2003b) has suggested the decomposition

$$P^{t-1,t} = P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t}, \tag{18}$$

where the change in the domestic price index is

$$P_S^{t-1,t} = \frac{p_E^t}{p_E^{t-1}}, \tag{19}$$

[9]Although the sample periods are not identical, our results are broadly consistent with results from previous studies using the same decomposition technique for Switzerland; Kohli (1993) for 1949–1988, and Kohli (2003a) for 1967–1996.

the (inverse of the) terms-of-trade effect is

$$G^{t-1,t} = \exp\left[\frac{1}{2}(s_M^{t-1} + s_M^t)\ln\frac{g^t}{g^{t-1}}\right], \tag{20}$$

with $g^t \equiv p_M^t / p_X^t$, and the change in the balance of trade is given by

$$H^{t-1,t} = \exp\left[\frac{1}{2}(s_B^{t-1} + s_B^t)\ln\frac{h^t}{h^{t-1}}\right], \tag{21}$$

with $h^t \equiv p_X^t / p_E^t$ and $s_B^t = s_X^t + s_M^t$.[10]

The relative prices g^t and h^t are plotted in Figure 4, with the solid lines representing the corresponding smoothed series. From the plot of g^t (the inverse of the terms of trade), it can be seen that the terms of trade improved over the period 1980 to 1995, but that there seems to have been a change in the trend since then. From the plot of h^t, it can be seen that the price of exports fell quite consistently over the sample relative to the price of domestic goods.

With (18), nominal GDP growth can be decomposed as follows:

$$\Gamma^{t-1,t} = R^{t-1,t} \cdot P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}. \tag{22}$$

This decomposition is well suited for the calculation of growth in real value added and growth in (Törnqvist) real GDP. Growth in real value added is

$$\Gamma^{t-1,t}/P_S^{t-1,t} = R^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}, \tag{23}$$

whereas growth in (Törnqvist) real GDP is

$$\begin{aligned} \Gamma^{t-1,t}/(P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t}) &= \Gamma^{t-1,t}/P^{t-1,t} \\ &= R^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}. \end{aligned} \tag{24}$$

Our calculations of the growth decomposition according to (22) indicate that the balance-of-trade effect, $H^{t-1,t}$, is negligible over the whole sample period. As a consequence, $P_S^{t-1,t}$ is close to $P_E^{t-1,t}$ and the terms-of-trade effect $G^{t-1,t}$ is virtually identical with the results for $A^{t-1,t}$ in Table 1.[11]. This means that the calculations based on (22) support our interpretation of the results we obtained for (16). Furthermore, we note that growth in real value added is virtually identical with growth in real net output in Table 1, whereas the discrepancy

[10] Notice that the contribution of changes in domestic prices to nominal GDP growth, $P_E^{t-1,t}$, is not the same as the rate of growth in domestic prices, $P_S^{t-1,t}$.

[11] Detailed results of the alternative decomposition are available from the authors on request

between growth in real value added and growth in real GDP essentially reflects terms-of-trade effects. Over the period 1981-2001, average growth in real value added (1.9%) was higher than average growth in real GDP (1.6%), where the difference between the two measures of real output is due to improvements in the terms of trade since the other potential source of differences, the balance of trade effect, is negligible. The difference between the two measures of real output was larger between 1981 and 1991 (0.5 percentage points) than between 1992 and 2001 (0.2 percentage points); again solely because of differential changes in the terms of trade between the two sub-periods. As emphasized by Kohli (2002), it makes a difference in the case of Switzerland whether economic growth is measured by real GDP or real value added. In most other countries, it does not matter much which concept is used.

With our interpretation of $A^{t-1,t}$ as a terms-of-trade-effect maintained, the results for the decomposition of output growth reported in Table 1 can be used to construct an index of the annual change in welfare arising from productivity growth and changes in the terms of trade. Productivity growth improves welfare by allowing more output to be produced with the same quantity of inputs. As Diewert and Morrison (1986) pointed out, improvements in the terms of trade also improve welfare because they allow the production of non-traded goods to be increased without changing the trade balance. Thus, we can interpret terms-of-trade changes over time as a type of productivity change which affects welfare in the same way as a change in productivity.

The welfare-change index proposed by Diewert and Morrison (1986) can be written as

$$W^{t-1,t} \equiv R^{t-1,t} \cdot A^{t-1,t}, \tag{25}$$

where $W^{t-1,t}$ denotes the change in welfare between $t-1$ and t. Whereas various sources of welfare are ignored in this index, it does measure the effects of two primary sources of aggregate welfare change, $R^{t-1,t}$ and $A^{t-1,t}$. The results for the welfare-change index are given in Table 2.[12] The geometric-mean values of the annual change in welfare provided at the bottom of the table reveal that the annual change in welfare amounted to 0.7% on average over the full period. The results for the two sub-periods are very close. However, there is considerable annual variation. For example, there was a positive change in welfare of 3% in 1986. From Table 1 we can see that this was driven entirely by the contribution of an improvement in the terms of trade, and not by productivity growth.

[12]The results for the "welfare gap" displayed in the same table are discussed in Section 5.2.

4.2 The National Income Function Approach

In Section 4.1, we emphasized the roles of labour input, capital input, productivity, the terms of trade, and domestic prices. In this section, the focus is on the dual price and quantity variables, i.e., factor prices, productivity, the demand for goods, and the structure of foreign trade.

Using (12), (13) and (14) with $a = t - 1$ and $b = t$, the growth in nominal national income, $C^{t-1,t}$, can be decomposed according to

$$\mathcal{C}^{t-1,t} = (1/\mathcal{R}^{t-1,t}) \cdot \mathcal{Y}_E^{t-1,t} \cdot \mathcal{Y}_X^{t-1,t} \cdot \mathcal{Y}_M^{t-1,t} \cdot \mathcal{W}_L^{t-1,t} \cdot \mathcal{W}_K^{t-1,t}. \tag{26}$$

Note that $\mathcal{R}^{t-1,t} > 1$ implies that TFP growth reduces costs (i.e. payments to the factors of production). The other variables in (26) denote the contributions to nominal income growth from changes in the quantity of domestic expenditures ($\mathcal{Y}_E^{t-1,t}$), the quantity of exports ($\mathcal{Y}_X^{t-1,t}$), the quantity of imports ($\mathcal{Y}_M^{t-1,t}$), labour prices ($\mathcal{W}_L^{t-1,t}$), and capital prices ($\mathcal{W}_K^{t-1,t}$).

The national income function approach provides a decomposition that is familiar from the National Accounts. It was proposed (and applied to U.S. data) by Kohli (2003c), who also provides a justification from the economic approach to index numbers for the use of the Törnqvist index formula for the output quantity and input price contribution indexes. The results we obtain from applying this approach to Swiss data are presented in Table 3.[13] Notice that $\mathcal{R}^{t-1,t}$ rather than $1/\mathcal{R}^{t-1,t}$ is reported, so that a value greater than one reduces national income. We can see from Table 3 that domestic expenditures and exports contributed positively to national income growth over each subperiod, but that productivity and imports have acted as a drag on growth. On average the contributions of exports and imports almost cancel each other out, so that the net effect from the trading sector is negligible.

The contributions from TFP growth are identical to those presented in Table 1, which were calculated from (3) as an implicit output index divided by a direct input index. As TFP growth in the income approach is calculated based on (12) as a direct output index divided by an implicit input index, this result indicates that the choice of which approach is used in the calculation of TFP is essentially irrelevant in this case.

Capital prices have made notable contributions to nominal income growth in some years (2.2% in 1989), but the contributions average out to be quite small over the whole sample. Labour prices on the other hand have contributed positively in every year, with a particularly strong contribution in the first subperiod. However, by falling significantly in the second

[13] The growth in nominal income is slightly different from the growth in nominal GDP, as reported in Table 1. This is due to the statistical discrepancy.

subperiod (from 3.4% to 1.5%), labour prices were the main contributor to the decline in nominal income growth (from 5.8% to 1.9%).

5 Decomposition of the GDP Gap

5.1 The GDP Function Approach

In this section, we turn to the decomposition of output gaps. The nominal GDP gap and its components are all defined as deviations of the respective variables from their long-run trends. The calculation of the trends has been described in Section 3. In Table 5, the first column gives trend nominal GDP, which was constructed by smoothing actual nominal GDP appearing in column 2. Column 3 shows the index for the nominal GDP gap, calculated as the ratio of column 2 to column 1. This ratio can be transformed into percentage deviations of actual from potential GDP by subtracting one and multiplying by one hundred.

Gap decomposition, like growth decomposition, can take various forms. Our first decomposition of the nominal output gap corresponds to (16). Using (11), (7) and (8), it is given by

$$\Gamma^t = R^t \cdot A^t \cdot P_E^t \cdot V_L^t \cdot V_K^t, \tag{27}$$

where, for example, A^t is a Törnqvist index of the contribution to deviations of actual GDP from trend associated with deviations of import and export prices from their trends. According to (27), the nominal GDP gap is decomposed into the contributions of the deviations from their respective trends of productivity (R^t), the terms of trade (A^t), domestic prices (P_E^t), the quantity of labour (V_L^t), and the quantity of capital (V_K^t).[14]

The alternative decomposition of the output gap, corresponding to (22), takes the form

$$\Gamma^t = R^t \cdot P_S^t \cdot G^t \cdot H^t \cdot X_L^t \cdot X_K^t. \tag{28}$$

In this alternative, nominal GDP gaps are decomposed into the contributions of the deviations of productivity (R^t), the domestic prices (P_S^t), the terms of trade (A^t), the balance of trade (H^t), the quantity of labour (X_L^t), and the quantity of capital (X_K^t) from their respective trends.

The results of decomposing the output gap according to (27) are displayed in Table 4. As in the case of growth decomposition, the gap decomposition according to (28) does not affect the picture we get from (27). We therefore restrict our discussion of the results to this

[14] For an application to U.S. data, see Fox and Warren (2001), for applications to New Zealand data see Fox, Kohli and Warren (2002, 2003) and for an application to Japanese data see Fox (2002).

decomposition. The results for the real-value-added gap correspond to those for the real gap in Table 4, whereas the results for the real GDP gap are virtually identical with the sum of the real gap and the terms-of-trade gap in the same table.

We find that both the nominal and the real gaps average out over the sample to be negligible. This is not surprising given the smoothing that is done to get the estimates of the gaps. However, the gaps can be substantial in any particular year. The largest positive real GDP gap is in 1990 (3.3%). Smaller, local peaks are observed in 1981 (0.7%), 1985 (0.4%) and 2000 (0.7%). Furthermore, we observe that in 1981 and 1990, both the labour gap and the productivity gap contributed positively to the real GDP gap. Yet in 1985 and 2000, only the productivity gap contributed positively, whereas the labour gap provided a drag on the output gap. The capital gap, in turn, is negligible over the whole sample period. Given that our measure of capital input disregards variations in the utilization of the capital stock in place, this is not surprising.

The variations in the terms-of-trade gap are substantial, and as a result the real-value-added gap and the real GDP gap often move in opposite directions. From the results given in Table 4, we can see that the two output gaps are of opposite sign in 8 out of 22 years. Although both gaps suggest that the economy peaked in 1990 (2.8% and 3.3%, respectively) and 2000 (0.4% and 0.7%), the they give different turning points on other occasions.

In Section 4.1, the results for the contributions of productivity and the terms of trade to output growth have been used to construct a welfare-change index. In a similar way, we can use the results for the productivity gap and the terms-of-trade gap from Table 4 to construct an index of the welfare gap. Following Fox and Warren (2001), the welfare-gap index is defined as

$$W^t \equiv R^t \cdot A^t. \tag{29}$$

This welfare gap tells us by how much welfare could have been improved (or reduced) if productivity growth and changes in the terms of trade were at their long-run trend levels, holding constant changes in factor endowments and the prices of non-traded goods.

The results are given in Table 2. Overall, the welfare gaps turn out to be rather small. The main reason is that in 15 out of 22 years the productivity gap and the terms-of-trade gap do not have the same sign. The largest positive welfare gap is measured in 1986 (1.3%) when both productivity and the terms of trade slightly exceeded their trends. The largest shortfalls of welfare from its trend date from 1982 and 1983 (-1.2%). Productivity was the source of these shortfalls, outweighing small positive contributions of the terms of trade.

5.2 The National Income Function Approach

The decomposition of the national income gap, from (12), (13) and (14), can be written as

$$\mathcal{C}^t = (1/\mathcal{R}^t) \cdot \mathcal{Y}_E^t \cdot \mathcal{Y}_X^t \cdot \mathcal{Y}_M^t \cdot \mathcal{W}_L^t \cdot \mathcal{W}_K^t. \tag{30}$$

This is the gap counterpart to the growth decomposition in (26). According to (30), the nominal income gap can be decomposed into the the contributions of deviations from their respective trends of productivity ($\mathcal{R}^t$), the quantity of domestic expenditures ($\mathcal{Y}_E^t$), the quantity of exports ($\mathcal{Y}_X^t$), the quantity of imports ($\mathcal{Y}_M^t$), labour prices ($\mathcal{W}_L^t$), and capital prices ($\mathcal{W}_K^t$).

Table 5 reports the results. We see that the real income gap, driven by a 4% contribution from the domestic expenditures gap, was the main source of the deviation of nominal income from trend in 1990, the year with the largest gap. The other components play notable roles in other years, such as 1992 when the labour price gap contributed 2.3% to the nominal gap.

The insight that this decomposition of the nominal income gap provides is in terms of real gaps and coincident or subsequent contributions to the nominal gap from trend deviations of labour and capital prices. A real output gap is often taken as an indicator of inflationary pressure. From Table 5, we can see that the positive real income gap of 2% in 1990 and 1.4% in 1991 was followed by five consecutive years (1991-1995), where the labour price deviated from its trend and contributed positively to the nominal gap. While correlation does not imply causation and the small sample period precludes statistical analysis of the relationship, it appears that the price of labour deviates from trend with a lag after a correspondingly signed real gap.

6 Concluding Remarks

We have provided estimates from various complementary ways of decomposing output gaps and growth for Switzerland. Each method provides its own insights, and each is firmly based on microeconomic theory.

For the period 1980 to 2001, three alternative definitions of real output were used to examine the sources of output growth. "Real net output growth" is the growth in nominal GDP deflated by an index of the contribution of domestic expenditures to nominal GDP. This definition treats the terms of trade as a real, productivity-type effect. "Real value added growth" deflates nominal GDP growth by simply the price index for domestically traded goods, again leaving a role for the terms of trade as a real effect, along with a balance of trade effect. Finally, "real GDP growth" was defined as nominal GDP growth divided by an aggregate price index over domestic and traded goods, as per the standard statistical agency definition.

It was found that capital formation is the largest contributor to real net output growth, followed by total factor productivity and movements in the terms of trade. The slowdown in growth over the period 1992 to 2001 can be attributed to falls in the contributions from labour and capital utilization, and the terms of trade. The use of alternative real output concepts shows the potential sensitivity of conclusions relating to aggregate economic performance. For example, real value added (which includes the terms of trade as a real effect) exceeded the growth of real GDP by more than 3% in 1986, due to an improvement in the terms of trade.

The national income approach allows the sources of growth to be examined from the other side of the national accounts balance sheet. It was found that domestic expenditures and exports contributed positively over the sample, but that productivity and imports have acted as a drag. The effects from exports and imports approximately offset each other so that the net effect of the trading sector is negligible.

The same forms of decompositions applied to account for the sources of output growth were also applied to decompose sources of the output gap in each period. It was found that labour utilization and productivity have consistently been sources of deviations of real net output from trend over the sample. In the first half of the sample there were some notable contributions from the terms of trade. These contributions are reflected in the substantial differences between real value added gaps and real GDP gaps, yielding gaps of opposite sign in 8 out of 22 years.

Finally, it can be emphasized that productivity and the terms of trade can have important real effects that cause output in any period to deviate from its long run trend. For example, an increase in productivity growth is a real effect which will, other things constant, cause real output (however measured) to deviate from its long-run trend. There are no immediate inflationary effects of this deviation from trend, yet treating trend output as equivalent to potential output would routinely suggest that such deviations are demand driven and therefore inflationary. Since the decompositions presented in this paper draw attention to the sources of growth and output gaps, they may facilitate more informed policy responses.

Appendix: Smoothing

Using the Super Smoother technique, the smooth function, $S_{t,t-1}$, is built pointwise as follows.

1. The k nearest neighbours to some point R^0 define the "span". Observations which lie within this span are said to be within a neighbourhood, $N(R^0)$, of R^0. The choice of the span is discussed below.

2. The largest distance between R^0 and another point in $N(R^0)$ is calculated:

$$\Delta R^0 = max_{N(R^0)}|R^0 - R^i|. \tag{31}$$

3. A tri-cube weight function is used to assign weights to each point in $N(R^0)$:

$$W\left(\frac{|R^0 - R^i|}{\Delta R^0}\right), \tag{32}$$

   where

$$W(u) = \begin{cases} (1-u^3)^3 & \text{for } 0 \leq u < 1 \\ 0 & \text{otherwise.} \end{cases} \tag{33}$$

4. Using these weights, the weighted least squares fit of R^0 on $N(R^0)$ is calculated, and the fitted value is taken to be S^0.

5. This procedure is repeated for each observation.

For a fixed span, the above describes locally weighted regression smoothing (Lowess). A constant span may be inappropriately restrictive. Super Smoother chooses the span for each observation based on the cross-validation criterion (Schmidt, 1971; Stone, 1974):

$$CV(k) = (1/k)\sum_{i=1}^{k}[R^i - S^{-i}(R^i|k)]^2, \tag{34}$$

where S^{-i} denotes the smoothed value of R^i calculated by dropping R^i and using the R_j in the neighbourhood $N(R^0)$ of span k as predictors of R^i. The span which minimizes $CV(k)$ is selected for each R^i.

Super Smoother comes as an option in statistical packages such as S-PLUS (Statistical Sciences, 1995).

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Table 1: Decomposition of GDP Growth

Year	NGDP	Domestic Prices	TFP	Terms of Trade	Labour	Capital	Real Net Output
1981	1.075	1.066	0.998	0.995	1.003	1.012	1.008
1982	1.051	1.046	0.986	1.018	0.990	1.012	1.005
1983	1.032	1.021	1.002	1.007	0.993	1.009	1.011
1984	1.069	1.034	1.019	1.001	1.002	1.010	1.033
1985	1.061	1.033	1.012	0.993	1.010	1.011	1.027
1986	1.050	1.000	0.999	1.031	1.008	1.011	1.050
1987	1.038	1.012	0.993	1.013	1.008	1.012	1.026
1988	1.062	1.038	1.004	0.993	1.014	1.012	1.023
1989	1.079	1.040	1.019	0.992	1.014	1.013	1.037
1990	1.084	1.038	1.012	1.006	1.013	1.013	1.045
1991	1.048	1.049	0.987	1.008	0.991	1.014	0.999
1992	1.022	1.022	1.011	0.998	0.981	1.011	1.000
1993	1.021	1.011	1.000	1.011	0.991	1.007	1.010
1994	1.026	1.002	1.002	1.014	1.002	1.006	1.024
1995	1.012	1.002	0.995	1.007	1.001	1.008	1.010
1996	1.005	1.002	1.001	0.997	0.996	1.008	1.003
1997	1.018	1.007	1.015	0.991	0.997	1.007	1.010
1998	1.025	0.994	1.012	1.005	1.008	1.007	1.032
1999	1.020	1.008	1.001	0.998	1.004	1.008	1.012
2000	1.044	1.021	1.023	0.988	1.006	1.007	1.023
2001	1.017	1.007	0.994	0.999	1.010	1.007	1.009
Geometric Means							
1981-01	1.041	1.021	1.004	1.003	1.002	1.010	1.019
1981-91	1.059	1.034	1.003	1.005	1.004	1.012	1.024
1992-01	1.021	1.008	1.005	1.001	0.999	1.008	1.013

Table 2: Welfare Indexes

Year	Welfare Change	Welfare Gap
1980		1.004
1981	0.993	0.991
1982	1.003	0.988
1983	1.008	0.988
1984	1.021	0.999
1985	1.006	0.995
1986	1.030	1.013
1987	1.006	1.009
1988	0.997	0.996
1989	1.010	0.998
1990	1.018	1.007
1991	0.995	0.996
1992	1.009	0.997
1993	1.012	1.001
1994	1.016	1.009
1995	1.002	1.004
1996	0.998	0.995
1997	1.006	0.995
1998	1.017	1.006
1999	0.999	1.000
2000	1.010	1.006
2001	0.993	0.994
Geometric Means		
1980-01	1.007	1.000
1980-91	1.008	0.999
1992-01	1.006	1.001

Table 3: Decomposition of GDP Growth: Income Approach

Year	Nominal Income	TFP	Domestic Expenditures	Exports	Imports	Labour Price	Capital Price	Real Net Income
1981	1.074	0.998	0.985	1.023	1.005	1.045	1.012	1.015
1982	1.051	0.986	0.991	0.994	1.002	1.053	0.996	1.002
1983	1.030	1.002	1.016	1.006	0.982	1.033	0.994	1.003
1984	1.071	1.019	1.033	1.029	0.970	1.021	1.036	1.012
1985	1.055	1.012	1.019	1.029	0.987	1.025	1.007	1.022
1986	1.044	0.999	1.043	1.005	0.972	1.029	0.995	1.019
1987	1.032	0.993	1.028	1.005	0.980	1.023	0.990	1.020
1988	1.063	1.004	1.025	1.022	0.984	1.024	1.012	1.026
1989	1.081	1.019	1.044	1.022	0.980	1.030	1.022	1.027
1990	1.085	1.012	1.040	1.010	0.989	1.041	1.015	1.027
1991	1.053	0.987	0.989	0.995	1.007	1.055	0.994	1.004
1992	1.026	1.011	0.979	1.011	1.012	1.041	0.995	0.991
1993	1.020	1.000	0.993	1.005	1.000	1.018	1.004	0.998
1994	1.027	1.002	1.026	1.007	0.978	1.004	1.015	1.008
1995	1.005	0.995	1.014	1.002	0.987	1.013	0.983	1.008
1996	1.007	1.001	1.003	1.013	0.990	1.005	0.997	1.005
1997	1.019	1.015	1.005	1.041	0.974	1.011	1.003	1.004
1998	1.022	1.012	1.037	1.016	0.975	1.003	1.004	1.015
1999	1.009	1.001	1.003	1.026	0.985	1.010	0.987	1.012
2000	1.038	1.023	1.020	1.051	0.966	1.023	1.001	1.013
2001	1.022	0.994	1.022	1.001	0.987	1.024	0.982	1.017
Geometric Means								
1981-01	1.039	1.004	1.015	1.015	0.986	1.025	1.002	1.012
1981-91	1.058	1.003	1.019	1.013	0.987	1.034	1.007	1.016
1992-01	1.019	1.005	1.010	1.017	0.985	1.015	0.997	1.007

Note: The column labelled "TFP" is the index $\mathcal{R}^{t-1,t}$, so that the contribution to income (cost) growth is the inverse of the reported numbers. That is, index values greater than one in the TFP column represent cost reducing productivity growth.

Table 4: Decomposition of the Output Gap

Year	Potential GDP	Actual GDP	Nominal Gap	Domestic Prices	Productivity	Terms of Trade	Labour	Capital	Real Gap
1980	185713	183077	0.986	0.983	1.003	1.001	1.000	1.000	1.003
1981	196112	196807	1.004	1.008	1.002	0.990	1.004	1.000	0.996
1982	206756	206795	1.000	1.016	0.987	1.001	0.996	1.001	0.985
1983	217316	213457	0.982	1.005	0.987	1.001	0.990	0.999	0.978
1984	228765	228136	0.997	1.009	1.002	0.997	0.991	0.999	0.988
1985	241007	242045	1.004	1.015	1.011	0.984	0.996	0.998	0.989
1986	254140	254094	1.000	0.992	1.005	1.008	0.997	0.998	1.008
1987	268885	263743	0.981	0.978	0.993	1.016	0.996	0.998	1.003
1988	285053	280129	0.983	0.986	0.992	1.005	1.002	0.998	0.996
1989	301836	302165	1.001	0.995	1.005	0.993	1.010	0.999	1.007
1990	318416	327584	1.029	1.001	1.013	0.995	1.020	1.000	1.028
1991	333261	343265	1.030	1.020	0.996	0.999	1.011	1.003	1.009
1992	345664	350807	1.015	1.019	1.004	0.993	0.995	1.004	0.996
1993	355677	358326	1.007	1.014	1.002	0.999	0.990	1.002	0.993
1994	363769	367730	1.011	1.006	1.002	1.007	0.996	1.000	1.005
1995	370487	372251	1.005	1.002	0.993	1.011	1.000	0.999	1.003
1996	377249	373993	0.991	0.999	0.989	1.006	0.997	1.000	0.993
1997	384745	380593	0.989	1.001	0.998	0.997	0.993	1.000	0.988
1998	393168	390191	0.992	0.990	1.002	1.004	0.997	0.999	1.003
1999	402407	397894	0.989	0.991	0.995	1.005	0.998	1.000	0.998
2000	412435	415529	1.008	1.004	1.009	0.996	0.998	1.000	1.004
2001	422392	422485	1.000	1.003	0.995	0.999	1.003	1.000	0.997
Means									
1980-01	312057	312323	1.000	1.002	0.999	1.000	0.999	1.000	0.999
1980-91	253105	253441	1.000	1.001	0.999	0.999	1.001	0.999	0.999
1992-01	382799	382980	1.001	1.003	0.999	1.002	0.997	1.000	0.998

Note: The arithmetic mean is used to average over the GDP values, while the geometric mean is used to average over the indexes. The GDP values are in millions of Swiss francs.

Table 5: Decomposition of the Output Gap: Income Approach

Year	Nominal Gap	Productivity	Domestic Expenditures	Exports	Imports	Labour Price	Capital Price	Real Gap
1980	0.994	1.003	1.020	1.000	0.982	0.993	1.001	0.999
1981	1.009	1.002	0.995	1.010	1.002	0.998	1.006	1.005
1982	1.004	0.987	0.977	0.991	1.017	1.012	0.995	0.997
1983	0.983	0.987	0.979	0.984	1.014	1.010	0.983	0.990
1984	1.002	1.002	0.992	0.998	1.001	1.001	1.012	0.989
1985	1.005	1.011	0.987	1.011	1.007	0.998	1.013	0.995
1986	0.996	1.005	1.000	1.001	0.999	1.000	1.001	0.995
1987	0.973	0.993	0.998	0.992	0.997	0.994	0.984	0.994
1988	0.977	0.992	0.996	1.000	0.995	0.987	0.990	1.000
1989	0.997	1.005	1.017	1.010	0.986	0.983	1.006	1.008
1990	1.025	1.013	1.040	1.010	0.984	0.990	1.015	1.020
1991	1.030	0.996	1.017	0.997	0.996	1.011	1.004	1.014
1992	1.018	1.004	0.990	1.001	1.012	1.023	0.996	0.999
1993	1.009	1.002	0.979	0.998	1.018	1.017	1.000	0.992
1994	1.015	1.002	0.997	0.995	1.005	1.004	1.015	0.996
1995	1.004	0.993	1.003	0.986	1.004	1.004	1.000	0.999
1996	0.995	0.989	0.995	0.981	1.011	0.999	0.999	0.997
1997	0.996	0.998	0.986	1.000	1.004	1.000	1.004	0.993
1998	0.998	1.002	1.007	0.992	1.000	0.991	1.011	0.997
1999	0.985	0.995	0.994	0.993	1.006	0.987	1.001	0.997
2000	0.999	1.009	0.997	1.017	0.993	0.994	1.007	0.998
2001	0.998	0.995	1.003	0.992	1.003	1.002	0.993	1.003
Means								
1980-01	1.000	0.999	0.998	0.998	1.002	1.000	1.002	0.999
1980-91	0.999	0.999	1.001	1.000	0.998	0.998	1.001	1.000
1992-01	1.002	0.999	0.995	0.996	1.006	1.002	1.003	0.997

Note: The arithmetic mean is used to average over the income values, while the geometric mean is used to average over the indexes. The income values are in millions of Swiss francs. The column labelled "Productivity" is the index $\mathcal{R}^t$, so that the contribution to the income (cost) gap is the inverse of the reported numbers. That is, index values greater than one in the Productivity column represent gap-reducing productivity.

Figure 1: Prices

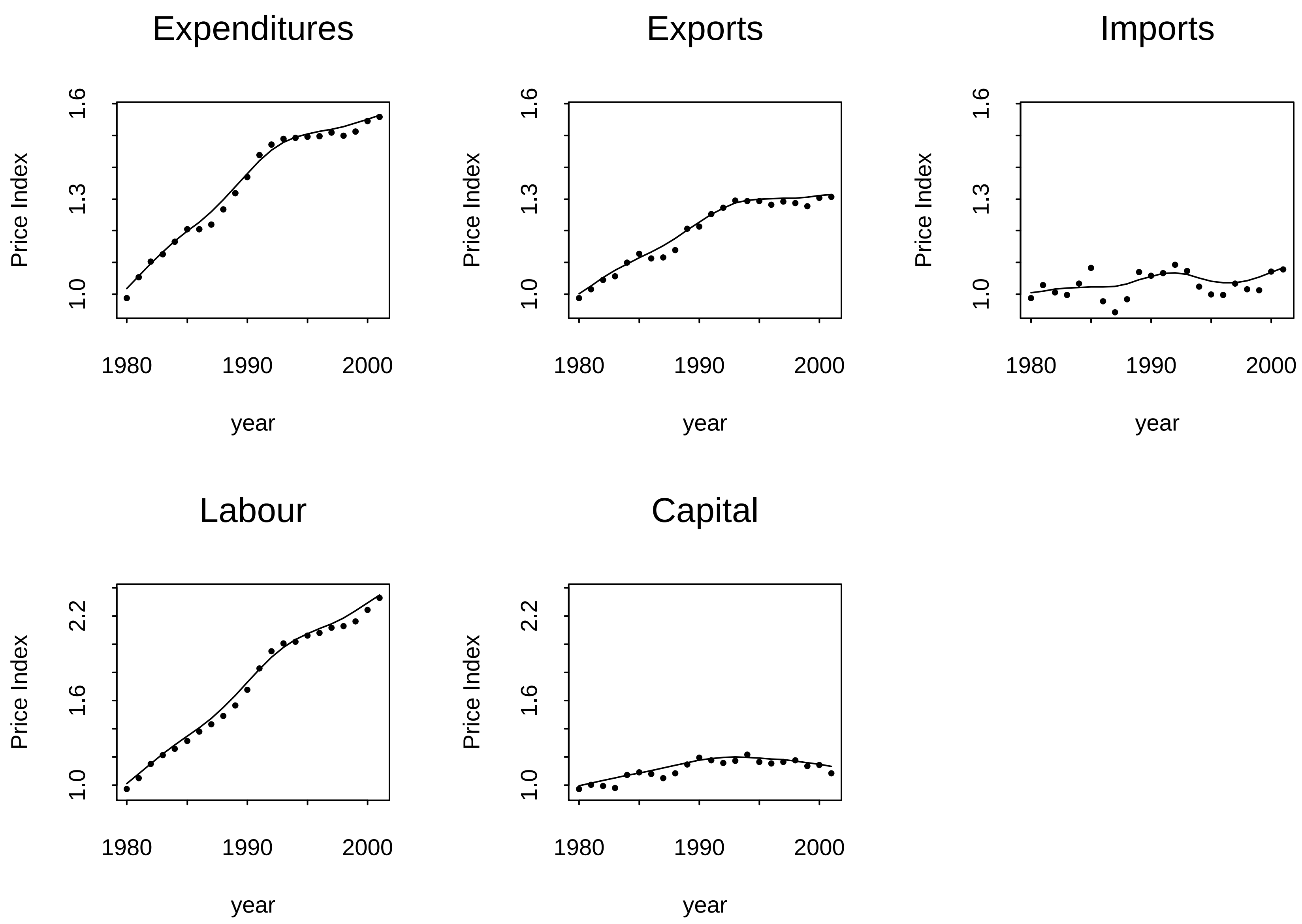


Figure 2: Quantities

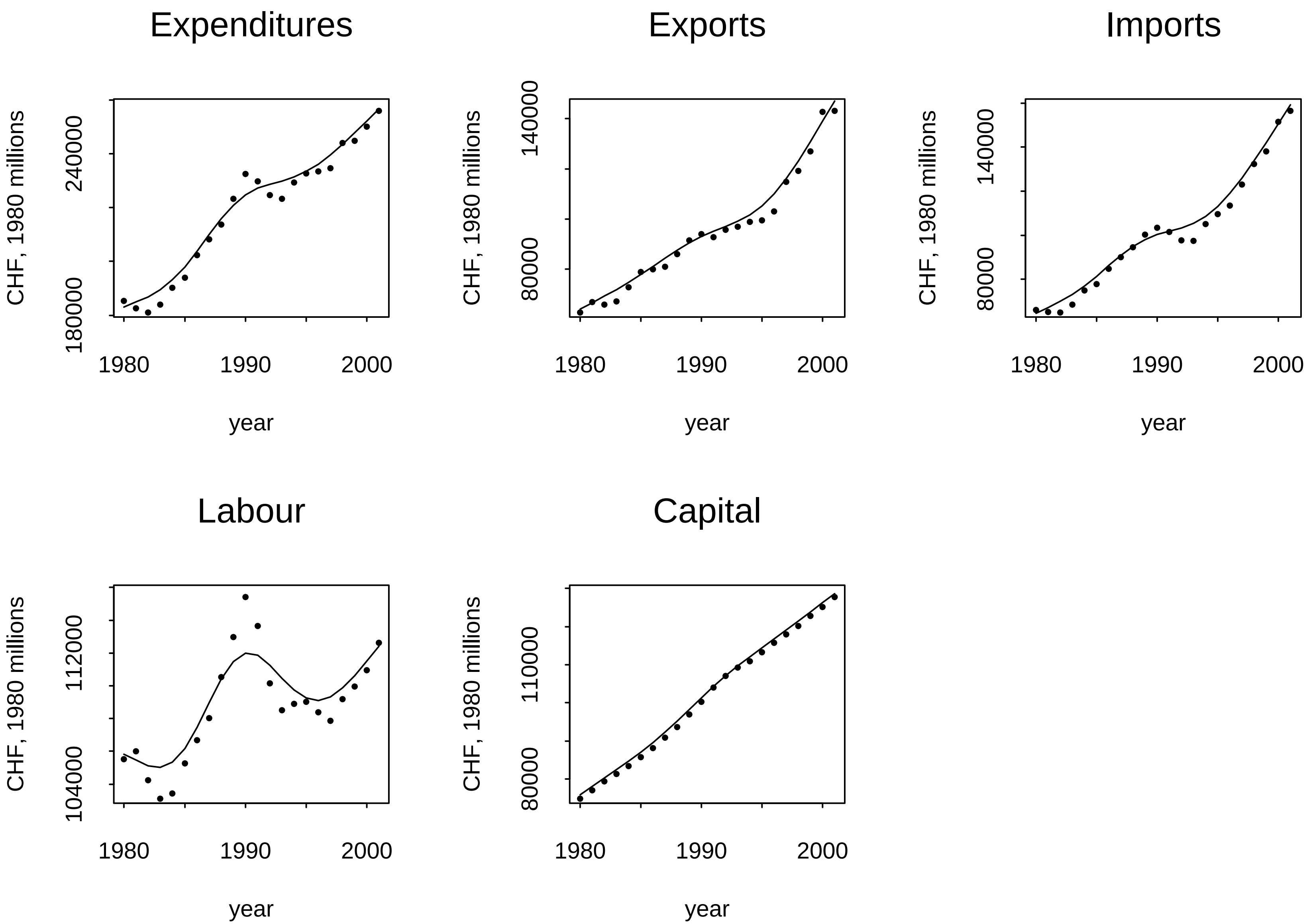
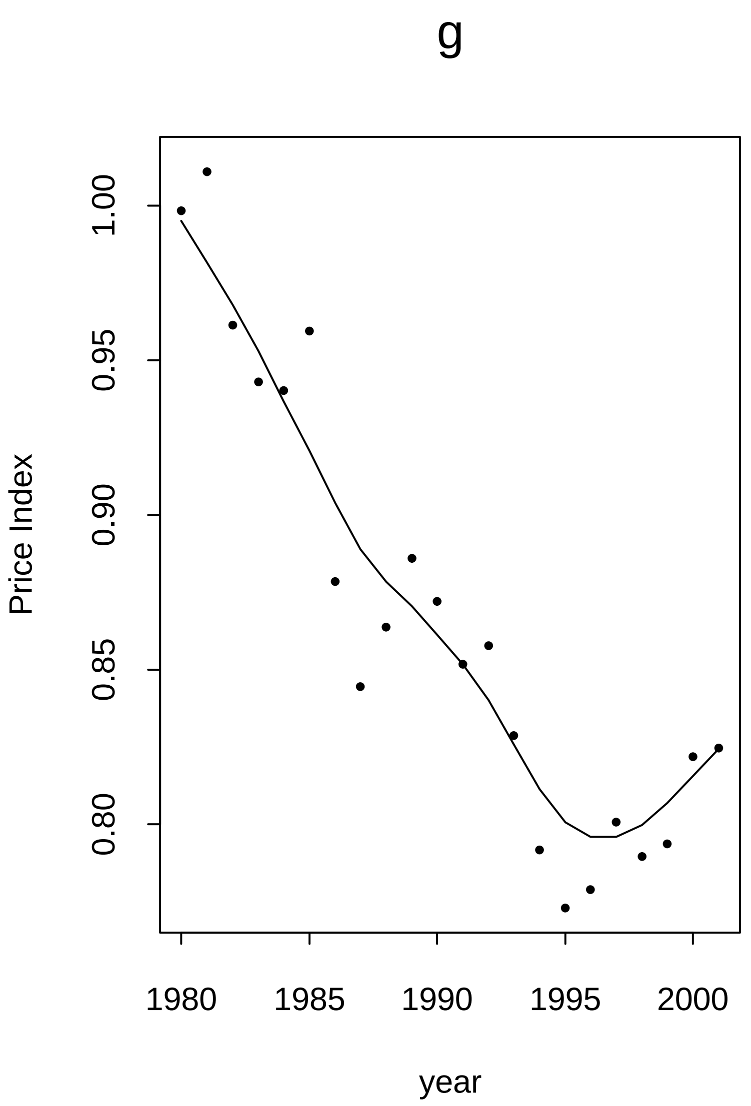
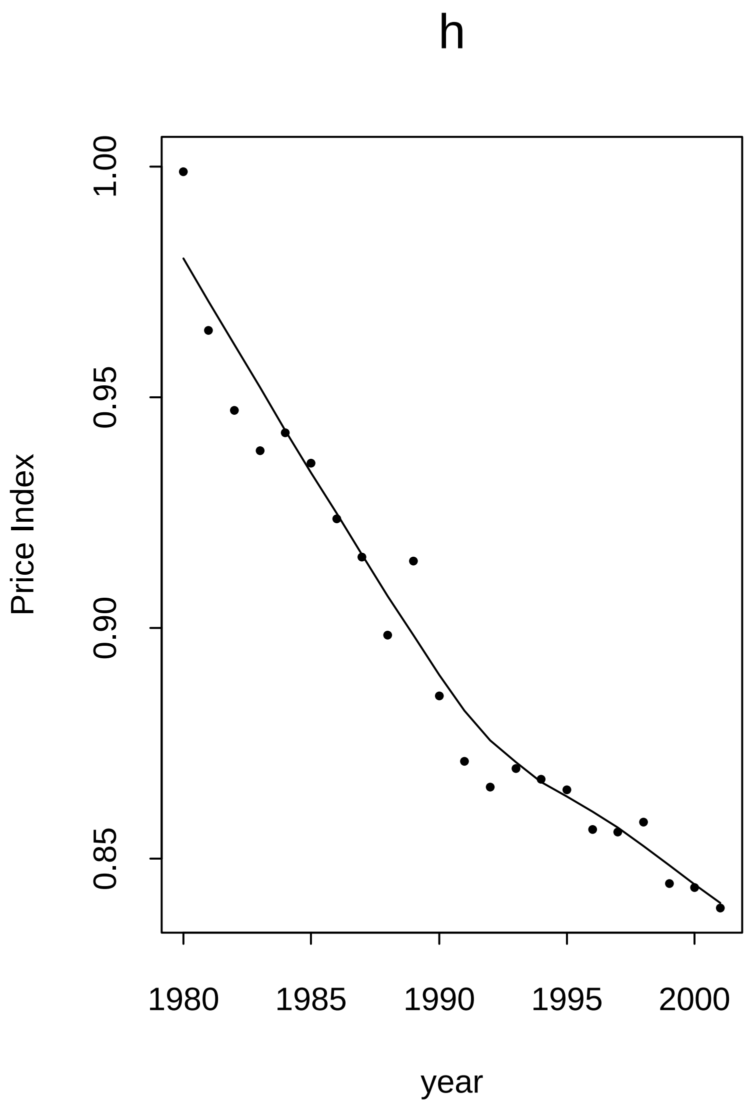


Figure 3: Real Net Output

Figure 4: Relative Prices





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