Applying the Hirose-Kamada filter to Swiss data: Output gap and exchange rate pass-through estimates

Franziska Bignasca and Enzo Rossi

2007-10

SCHWEIZERISCHE NATIONALBANK
BANQUE NATIONALE SUISSE
BANCA NAZIONALE SVIZZERA
BANCA NAZIUNALA SVIZRA
SWISS NATIONAL BANK

Swiss National Bank Working Papers

ISSN 1660-7716

Applying the Hirose-Kamada filter to Swiss data: Output gap and exchange rate pass-through estimates

Franziska Bignasca* and Enzo Rossi**

October 2007

Abstract

Multivariate filters based on the Hodrick-Prescott filter are appealing because they combine the advantages of the Hodrick-Prescott filter with economic relationships. Recently, a new multivariate filter has been put forward by Hirose and Kamada (2003). In this article we apply this new filter to Swiss data spanning the period from 1981 to 2005. We estimate both potential output and the associated output gap with quarterly data. Moreover, a model-consistent Phillips curve for an open economy is derived from simple economic relationships. Based on the estimated Phillips curve, we investigate exchange-rate pass through effects on consumer prices. We find only a weak transmission of exchange rate fluctuations into consumer prices.

Keywords: potential output, output gap, multivariate filter, Hirose and Kamada filter, exchange-rate pass through

JEL Classification Number: E31, E32, F41

* UBS, CCRC Country Risk Analysis, Zurich
** Swiss National Bank, Research Department, Zurich
The views expressed in this paper are those of the authors and not necessarily those of UBS or the Swiss National Bank. The authors are particularly indebted to Peter Kugler and Mathias Zurlinden for helpful discussions and comments. The authors would also like to thank Marco Huwiler, Barbara Rudolf, Eveline Ruoss and an anonymous referee for their suggestions. All remaining errors are, of course, those of the authors.
Contact information: Franziska Bignasca, UBS, franziska.bignasca@ubs.com

1. Introduction

Measures of potential output and consequently of the output gap convey important information for both monetary and fiscal policymakers. For monetary authorities this information is of great interest when appraising inflation risks. Potential output is defined as the level of production consistent with long-run price stability. The output gap is the percentage deviation between actual output and potential output. When output is above potential production (positive output gap) resources are used in excess. The economy is overheating and inflation pressure mounting. Hence the central bank should become more restrictive in order to prevent an acceleration in inflation. Equally important is the rate of potential output growth. If potential output growth increases, the economy's output can develop at a higher rate without overheating, allowing a central bank a more expansive policy than in the past. Moreover output gaps enter as an input into macro models and monetary policy reaction functions like the Taylor rule. Output gaps are also used to compute cyclically adjusted fiscal variables to assess fiscal policy stance.

Measures of potential output and the output gap cannot be observed and need to be estimated by means of statistical/econometric methods. There is no standard way to address this issue. The options range from univariate filters to multivariate filters, and from structural methods like the production function method and structural VARs to survey-based estimates of output gap. In this paper we use a multivariate filter that has been proposed by Hirose and Kamada (2003). It presents interesting features. First, it embeds economic information in the process of determining potential output. Second, it exploits the advantages of the univariate Hodrick-Prescott filter (HP filter). Finally, it allows us to construct confidence intervals to assess the reliability of the estimated series. The Hirose-Kamada filter is akin to the filter of Laxton and Tetlow (1992) since both belong to the family of multivariate filters based on the HP filter.

Using quarterly Swiss data from 1981 Q1 to 2005 Q4, we estimate and compare the results for the output gap across these three filters, i.e. the Hirose-Kamada filter, the HP filter and the Laxton-Tetlow filter. From the mid-1990s onwards, the estimates diverge. In particular, the Hirose-Kamada filter suggests a more marked underutilisation of resources than the other two filters. The Hirose-Kamada filter is also used to assess exchange rate pass-through effects. We find a low pass-through to consumer prices for Switzerland.

The rest of the paper is structured as follows. After briefly reviewing the theoretical properties and discussing the advantages and drawbacks of the HP filter, the Laxton-Tetlow filter and the Hirose-Kamada filter in section 2, we present and compare the results for the output gap in section 3. In section 4, we present estimates of the exchange rate pass-through. The final section offers some conclusions.

2. HP filter-based methods

The HP filter

The HP filter is one of the most widely used approaches for determining the output gap.[1] It is based on the assumption that a given time series, y_t, is decomposed into a trend component y_t^p and a cyclical component y_t^c:

$$y_t = y_t^p + y_t^c \tag{1}$$

The trend component y_t^p can be obtained by minimising the following programming problem:

$$\min_{\{y_t^p\}_{t=-1}^{T}} \left\{ \sum_{t=1}^{T} (y_t - y_t^p)^2 + \lambda_{HP} \sum_{t=1}^{T} ((y_t^p - y_{t-1}^p) - (y_{t-1}^p - y_{t-2}^p))^2 \right\} \tag{2}$$

The series y_t^p must satisfy the following conditions: 1) its deviations from the original series y_t must be as small as possible ($min \sum (y_t - y_t^p)^2$) and, 2) it has to exhibit a smooth path ($min \sum ((y_t^p - y_{t-1}^p) - (y_{t-1}^p - y_{t-2}^p))^2$).

The smoothing parameter λ_{HP} penalises variability in the trend component, since it determines the respective weight given to each of the two summation terms. If $\lambda_{HP} = 0$, all the weight is on goodness of fit to the original series, so that the estimated trend component, y_t^p, corresponds to the original series. If $\lambda_{HP} \to \infty$, all the weight is on a high degree of smoothness, so that y_t^p corresponds to a linear trend. While the results can be quite sensitive to the choice of the smoothing parameter λ_{HP}, its value has to be fixed by the authors in a discretionary way. As a rule, λ_{HP} is set equal to the values originally specified by Hodrick and Prescott (1997). These values are 100 for annual, 1600 for quarterly and 14400 for monthly data.

The output gap (in % of real GDP) is defined as the percentage difference between the real GDP series and the estimated trend component (or potential output), y_t^p. Expressed in logarithms, this reads as follows:

$$Output\ gap_t = (y_t - y_t^p) * 100 \tag{3}$$

where y_t is the logarithm of real GDP. Therefore, the output gap corresponds to the cyclical component (y_t^c) of real GDP multiplied by 100.

The key advantages of the HP filter are its straightforwardness and the good quality of results. However the HP filter has a number of drawbacks.[2] First, the choice of the smoothing parameter for estimates with annual and monthly data, in particular, has been questioned. Second, the filter has a tendency to mistakenly identify a cycle when a time series is difference

[1] The filter had already been drawn up in a working paper back in 1981, but was only published in Hodrick and Prescott (1997).

[2] For a critical assessment of the HP filter cf., among others, Harvey and Jaeger (1993), King and Rebelo (1993), Cogley and Nason (1995) as well as Guay and St-Amant (1996).

stationary. Third, it suffers from an end-point bias. In the case of an infinite sample, as assumed so far, the HP filter is symmetric and no phase shift results. With a finite sample, the filter loses the symmetry when all data points are considered. Under these circumstances, the relevant minimisation problem becomes:

$$\min_{\{y_t^p\}_{t=1}^{T}} \left\{ \sum_{t=1}^{T} (y_t - y_t^p)^2 + \lambda_{HP} \sum_{t=2}^{T-1} (\Delta y_{t+1}^p - \Delta y_t^p)^2 \right\} \tag{4}$$

where Δ is the first-differences operator.

In the literature, three possible solutions have been suggested in order to come to terms with the end-of-sample problem in finite samples. The first truncates the filter's weights at some given lag (Mills, 2003). The second extends the time series with forecast values (Kaiser and Maravall, 2001). The third takes advantage of the fact that λ_{HP} must not be constant for all observations. An example of the latter, which we will refer to later in this paper, can be found in Bruchez (2003).

The Laxton and Tetlow multivariate filter

In addition to the drawbacks pointed out in the previous section, the HP filter can also be criticised for filtering the GDP series on the basis solely of information contained in the time series itself. Laxton and Tetlow (1992) address this problem by extending the HP filter by two additional restrictions drawn from well-established economic relationships. The first is an expectations-augmented Phillips curve which describes the relationship between inflation, π_t, expected inflation, π_t^e, and the output gap. Assuming backward-looking inflation expectations, i.e. $\pi_t^e = a(L)\pi_{t-1}$, the Phillips curve may be written as follows:

$$\pi_t = a(L)\pi_{t-1} + \beta(y_t - y_t^p) + \varepsilon_t \tag{5}$$

where $a(L)$ indicates a polynomial in the lag operator.[3] β is the output-gap coefficient and ε_t is the error term.

The second is an Okun's law relationship which reflects an empirical regularity between the gap on the labour market (defined as the difference between the actual unemployment rate, U_t, and its trend, u_t^p) and the output gap:

$$U_t - u_t^p = c(L)(U_{t-1} - u_{t-1}^p) + d(L)(y_t - y_t^p) + \nu_t \tag{6}$$

where $c(L)$ and $d(L)$ are again polynomials in the lag operator and ν_t is the error term of the Okun's law relationship.

Incorporating both restrictions into the HP filter, the objective function to be minimised is:

[3] i.e. $a(L)w_t = (a_0 + a_1 L + a_2 L^2 + \cdots)w_t = a_0 w_t + a_1 w_{t-1} + a_2 w_{t-2} + \cdots$.

$$\min_{\{y_t^p\}_{t=1}^T} \left\{ \sum_{t=1}^{T} \lambda_{y_t} (y_t - y_t^p)^2 + \lambda_{HP} \sum_{t=2}^{T-1} (\Delta y_{t+1}^p - \Delta y_t^p)^2 + \sum_{t=1}^{T} \lambda_{\pi_t} \hat{\varepsilon}_t^2 + \sum_{t=1}^{T} \lambda_{U_t} \hat{v}_t^2 \right\} \tag{7}$$

where $\hat{\varepsilon}_t$, $\hat{v}_t$ represents the residuals from the estimated equations (5) and (6), respectively.

In the Laxton-Tetlow multivariate filter, the series to be determined (y_t^p) must satisfy several conditions. On the one hand, it must satisfy the conditions imposed by the HP filter. Therefore y_t^p must minimise the differences to the original series as well as the differences in the changes of y_t^p itself. On the other hand, y_t^p is set so that the sums of squared residuals from the Phillips curve and Okun's law relationship are minimised, i.e. the fit in the Phillips curve and in Okun's law relationship must be maximised.

Compared with the HP filter, three additional smoothing parameters ($\lambda_{y_t}, \lambda_{\pi_t}, \lambda_{U_t}$), which can vary in time, are considered. The structure of the estimation problem is circular since the determination of potential output depends on the residuals of both the Phillips curve and Okun's law relationship while, at the same time, the Phillips curve and Okun's law contain potential output as an argument. The problem can be solved by an iterative procedure. To begin with, potential output is estimated with the HP filter. This first estimation of potential output enters into both the Phillips curve and Okun's law relationships and the two equations (5) and (6) are estimated by OLS. The residuals from both regressions are used as arguments in (7) and the minimisation problem is solved. The new time series for potential output thus obtained is then used to re-estimate the two economic relationships. Iteration will be repeated until the coefficients of the Phillips curve and of the Okun's law relationship remain constant.[4] Note that unlike y_t^p, u_t^p is taken as given and can be obtained by applying the HP filter to U_t.

The key advantage of the Laxton-Tetlow filter is that it takes well-known economic relationships into consideration. Nevertheless it is also vulnerable when examined critically.[5] One tricky point is that the additional smoothing parameters must be set exogenously. Since few empirical values are available, this task turns out to be particularly difficult. Moreover, the results may react sensitively to the specifications of the economic relationships. Finally, adding structural information to the filter does not appear to amend the endpoint bias.

The Hirose-Kamada multivariate filter

Like Laxton and Tetlow (1992), Hirose and Kamada (2003) attempt to enrich the HP filter with information obtained from well-known economic relationships. They consider a Phillips curve, as described in the previous section in equation (5), but write the objective function to minimise as follows:

[4] For applications of this filter cf., e.g., Haltmaier (1996) and Conway and Hunt (1997). Rudolf (2001) illustrates the specification of the multivariate filter adopted by the Swiss National Bank.

[5] Cf. St-Amant and van Norden (1997).

$$V\left(a_0,\cdots,a_l,\beta,y_1^p,\cdots,y_T^p\right)\equiv\sum_{t=1}^{T}(\pi_t-a(L)\pi_{t-1}-\beta(y_t-y_t^p))^2+\lambda\sum_{t=2}^{T-1}(\Delta y_{t+1}^p-\Delta y_t^p)^2 \quad (8)$$

with *l+1* inflation lags included in the Phillips curve.

In this minimisation problem, the first summation term corresponds to an OLS estimation of the Phillips curve for given values of y_t and y_t^p. The second term imposes – as in the HP filter – a smoothing condition on y_t^p. Therefore the *k* coefficients in the Phillips curve and the trend component y_t^p are set so that the sum of the squared residuals of the Phillips curve is minimised and y_t^p achieves a smooth path.

Hirose and Kamada (2003) argue that it is inefficient to solve for all *T+k* unknowns at once. They suggest an iterative procedure that takes advantage of the properties of the minimisation problem. 1) For a given β, minimising $W\equiv V/\beta^2$ or $V(.)$ holds the same result. Rewriting W as:

$$W\left(a_0,\cdots,a_l,\beta,y_1^p,\cdots,y_T^p\right)\equiv\sum_{t=1}^{T}(z_t-y_t^p)^2+\lambda^*\sum_{t=2}^{T-1}(\Delta y_{t+1}^p-\Delta y_t^p)^2 \quad (9)$$

with $z_t\equiv y_t-\frac{\left(\pi_t-a(L)\pi_{t-1}\right)}{\beta}$ and $\lambda^*\equiv\lambda/\beta^2$

we obtain an equation that has the same form as the HP filter defined in (4). Therefore, by fixing the parameters at arbitrary values, y_t^p may be determined by means of the HP filter. 2) Taking y_t^p as given, minimising $V(.)$ with respect to $a_o,\cdots,a_l$ and β involves only the first term of the loss function. Hence the minimisation problem corresponds to an OLS estimation.

The iterative procedure can be described as follows. In the first step, the HP filter is applied to real GDP, ensuring a first estimation of potential output. This first estimation of potential output is used in the second step to estimate the parameters of the Phillips curve according to (5). In the third step, the time series z_t is calculated; and in the fourth step, the HP filter is applied to the series z_t according to (9), giving rise to a new estimation of potential output. The second to fourth steps are repeated until the coefficients of the Phillips curve no longer vary from one iteration to the next.

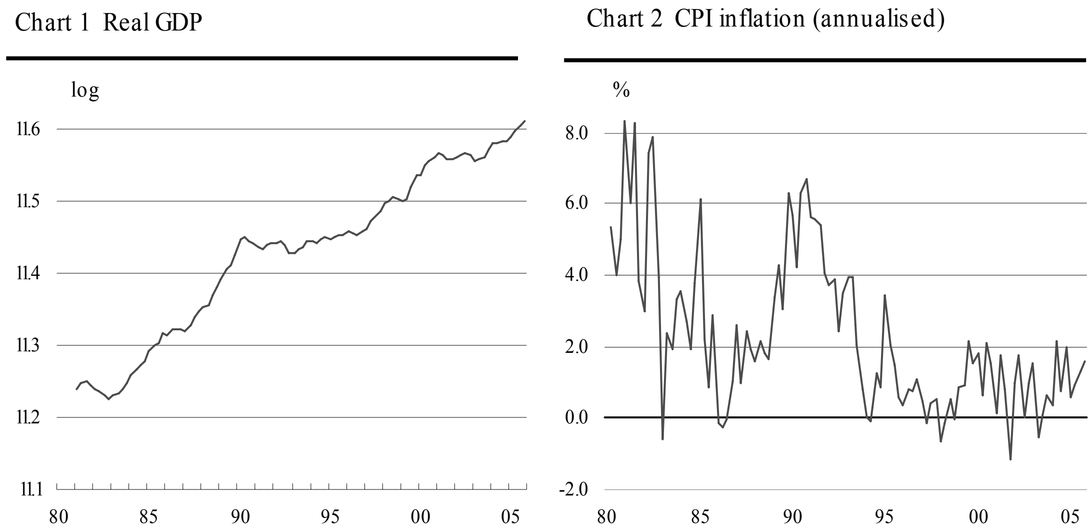
Although Laxton and Tetlow (1992) and Hirose and Kamada's (2003) estimation procedures are similar, the two filters differ from each other in the way the economic relationships are embedded in the HP filter. In the Hirose-Kamada filter, the economic relationship is directly integrated within the first term of the HP filter. As a consequence, only one economic relationship can be envisaged at a time. In the Laxton-Tetlow filter, the economic relationships are added to the original HP filter. Therefore, the number of economic relationships that can be considered is theoretically unlimited. However note that an exogenous smoothing parameter needs to be set for each economic relationship that is taken into account. Since only a few empirical values are available, the advantage of considering additional economic relationships must be put into perspective.

A further key element developed by Hirose and Kamada (2003) is a procedure for constructing confidence intervals around the estimates of potential output - and thus of the output gap. Confidence intervals convey valuable quantitative information on estimation uncertainty and thus raise the confidence placed in the size of the output gap. Interval calculations are based on the bootstrap method and are explained in the Appendix.

3. Swiss output gap estimated with the Hirose-Kamada filter

In this section we estimate potential output and the output gap for Switzerland for the period spanning 1981 Q1 to 2005 Q4. The estimation is based on quarterly real GDP provided by the State Secretariat for Economic Affairs (seco) and CPI data from the Swiss Federal Statistical Office (SFSO). The data have been seasonally adjusted using the Basic Structural model (BSM).[6] CPI inflation is defined as the logarithmic difference in the price level relative to the previous period, $\pi_t \equiv log(P_t) - log(P_{t-1})$. Chart 1 in Figure 1 illustrates the (logarithm of the) GDP series and Chart 2 the (annualised) inflation series.

Figure 1 Real GDP and CPI inflation



In specifications of the Phillips curve, the question arises as to whether inflation is to be modelled in levels or in first differences. Modelling inflation in levels reflects the assumption of inflation being stationary, whereas a specification in first differences assumes the presence of a unit root in the inflation rate. The assumption that inflation follows an I(1) process implies that shocks have a permanent effect on the future path of the inflation rate, i.e. the effects of a shock never die away. Moreover, it implies that the price index follows an I(2) process.

6 Cf. Harvey (1989).

Unit root tests, reported in the Appendix, are in part contradictory. On the whole they suggest that Swiss inflation follows an I(1) process. Both versions of the ADF test reject the null hypothesis of non-stationarity at the 5% level. The KPSS test rejects the null of stationarity in the case where only a constant is included, but supports the stationarity hypothesis when a constant and a trend are included. In contradiction to these test results, the ERS and the four tests proposed by Ng and Perron (2001) do not reject the unit root hypothesis.[7] Attempts to model the Phillips curve with inflation in first differences point to an over-differentiation.[8] For this reason, and given the partially contradictory results of the unit root tests, we conclude that Swiss inflation followed an I(0) process during the period investigated in this paper.

We model inflation expectations by assuming a backward-looking Phillips curve with two lags. By applying this lag specification we seek to minimise the risk that the residuals are autocorrelated. This is important for interpreting statistical tests and building confidence intervals, for the classic bootstrap assumes i.i.d. observations. In new bootstrap studies autocorrelated time series are allowed, but the results are less precise. However since we cannot exclude autocorrelation in spite of the test results, the presented estimation is obtained using the Newey-West HAC procedure and the stationary bootstrap by Politis und Romano (1994). The block length is chosen on the basis of the procedure used by Politis and White (2003).[9]

In order to tone down the problem of poor reliability of estimates at the end of the sample which is produced by the HP filter and the filters based on it, we first applied the method proposed by Bruchez (2003). The estimation results are given in Table 1, the estimated potential output is displayed in Figure 2 and the output gap in Figure 3. A comparison with the results obtained by extending the relevant series using forecast values follows at the end of this section.

7 Ng and Perron (2001) argue that conventional tests result in an over-rejection of the unit root hypothesis when the residuals display a large negative moving average root. This is the case for most inflation rate series.

8 Estimation results suggested the inclusion of four lags for the inflation rate in first differences to be appropriate. The sum of coefficients over the four variables resulted in a number greater than one, suggesting that the inflation rate was indeed over-differentiated. Moreover the development path for the output gap did not accord with Swiss experience.

9 Efron and Tibshirani (1993), among others, provide an introduction to the bootstrap method.

Table 1 Estimation results for the Phillips curve 1981 Q1 – 2005 Q4

Panel A		
variable	coefficient	*t*-statistics
constant	0.0048	6.3807
π_{t-1}	0.2895	2.6704
π_{t-2}	-0.1431	-1.2930
output gap$_t$	0.1250	7.2279
$\overline{R}^2 = 0.6693$		n = 100

Panel B				
Breusch-Godfrey LM test				
lag	2	4	8	12
$n\overline{R}^2$	2.4738	7.3302	12.4955	16.0357
critical values	5.9915	9.4877	15.5073	21.0261
p value	0.2903	0.1194	0.1304	0.1896

Note: HAC *t*-statistics

As indicated by an $\overline{R}^2$ of 67% (Panel A) the overall fit of the regression is quite satisfactory. The coefficient of the output gap is, as expected, positive and significantly different from zero. A 1% increase in the output gap raises annualised inflation *ceteris paribus* by 0.5%. Only the first lag of the inflation rate is significantly different from zero. The second lag was nonetheless included to minimise the risk of an autocorrelated structure in the residuals. This was tested by applying the Breusch-Godfrey LM test.[10] Test results for different lags, reported in Panel B, suggest no autocorrelation.

Further tests on the residuals indicate that these are normally distributed. The Jarque-Bera (JB) test does not reject the null hypothesis of normality at the 5% confidence level (JB statistic = 0.1054, critical value = 5.9915). The same qualitative information is displayed in the normal plot depicted in Chart 1 of Figure A1 in the Appendix. In this chart the residuals are plotted against the theoretical quantiles. If the residuals are normally distributed they fall in a straight line. Departures from the straight line indicate a skewed distribution, a distribution with fat tails, or the presence of outliers. All in all, the normal plot suggests no significant departure from the assumption of the residuals being normally distributed. Moreover, no significant outliers should be detected. This point is particularly important since the OLS estimator belongs to those estimators with a zero breakdown point. This means that a single outlier can lead to an estimate which can bring about any coefficients and standard errors. In order to verify this

[10] Since the estimation equation contains lagged endogenous variables, the assumption of strict exogeneity is violated and the Durbin-Watson test biased.

point, Chart 2 of Figure A1 reports the residuals against their related leverage. An observation with a high leverage has a high level of influence on the regression results, i.e. the estimated coefficients depend heavily on the inclusion of this observation. Therefore, outliers with a high level of leverage have to be considered critical, since not only do they indicate departures from normal distribution but they also have considerable influence on the regression results. In Chart 2 of Figure A1 this class of outliers would be located in the proximity of the right upper or right lower corner. As the chart shows, there are no residuals in these two critical regions. From this evidence, we conclude that the estimation results are not significantly biased by outliers.

Figure 2 displays the estimated potential output. Potential annual growth was about 1.9% over the investigated period. Splitting the sample into decades, we note that potential output growth has been on a declining path. After averaging 2.6% in the 1980s, it dropped to 1.7% during the subsequent decade. From 2000 to 2005, potential growth fell once more sharply, to 1.1% on average.

Figure 2 GDP and potential output in Switzerland, 1981 Q1 – 2005 Q4

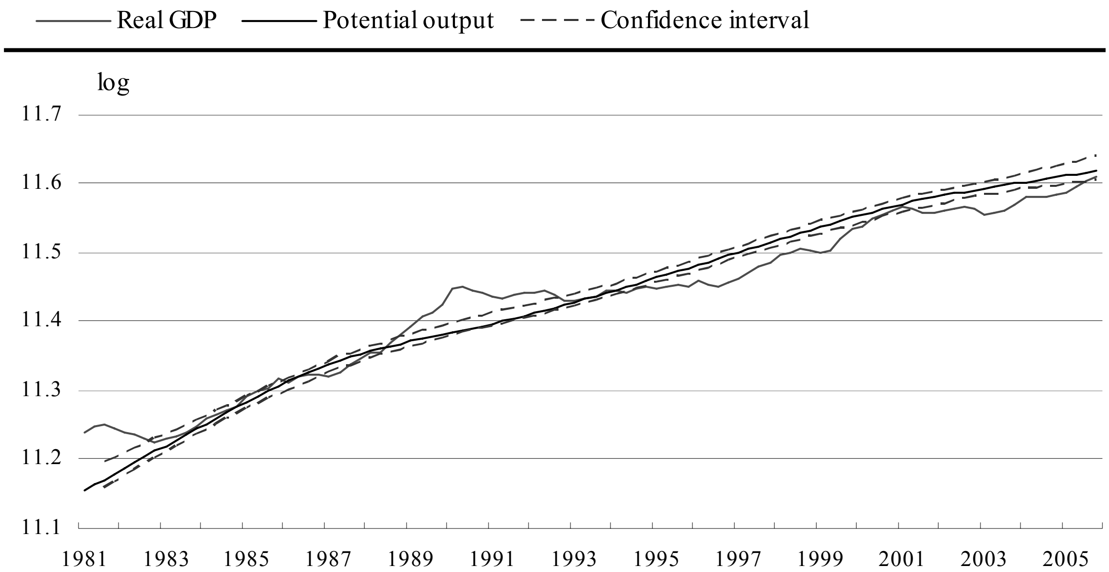
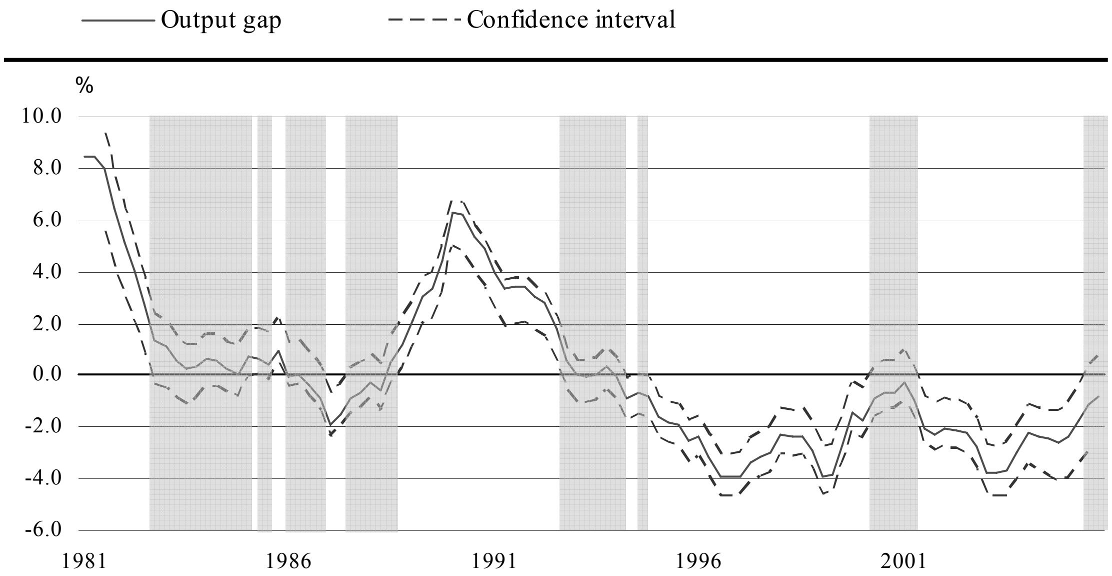


Figure 3 shows the corresponding output gap together with the 95% confidence intervals. From 1983 to 1988, the Swiss economy exhibited a sustained period of "normal" or equilibrium growth (shaded areas). Towards the end of the 1980s, the output gap grew increasingly positive, suggesting a GDP growth that strongly outpaced its potential. By contrast, from 1990 to 1996, the economy grew below potential. The output gap fell from +6.3% to -3.9%. Apart from a short spell in 2000/2001, during which it was closed, the output gap has been negative since 1994. Inflation has hovered about 0.9% since.

Figure 3 Output gap for Switzerland, 1981 Q1 – 2005 Q4



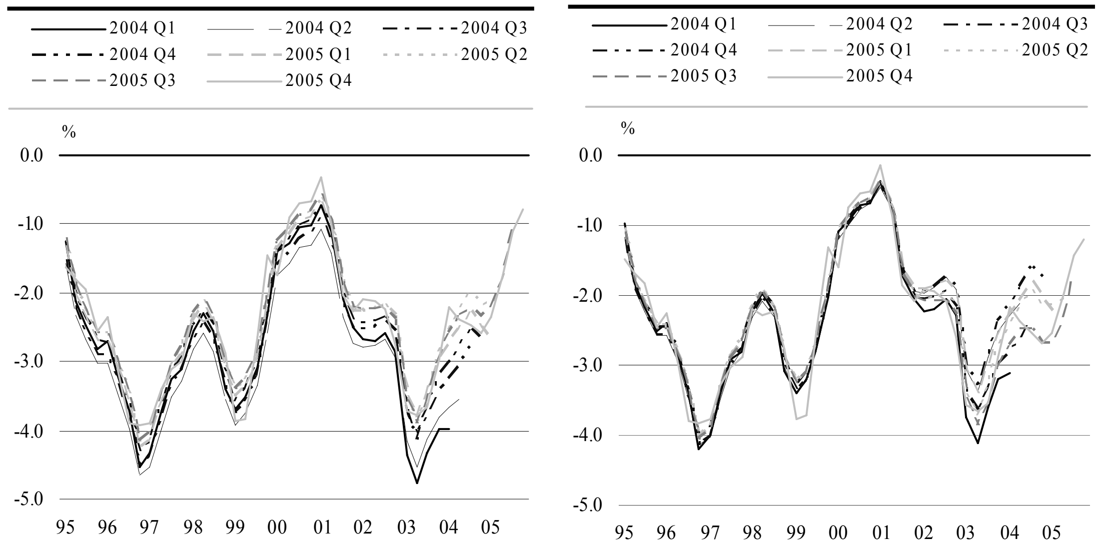
Note: The shaded areas correspond to the periods where the null line is included in the 95% confidence interval. In these cases, the output gap is not statistically different from zero and hence closed. The width of the confidence interval is about 2% on average.

As noted in section 2, one of the drawbacks of the HP filter which is inherited by the Laxton-Tetlow and Hirose-Kamada filters is the end-point bias. From a policymaker's point of view this is particularly unfortunate, since policy decisions are strongly dependent on current developments and thus on the current output gap estimations at the end of the sample.

This point is analysed in Figure 4. Using the information that was available at the prevailing time, we estimated the output gap by repeating the exercise from 2004 Q1 to 2005 Q4 in two different ways. First, we extended the time series by forecasts obtained by simple ARIMA processes (Chart 2 of Figure 4). Second, we adopted the modification proposed by Bruchez (2003) (Chart 1 of Figure 4). As can be seen in the charts, extending the time series by (ARIMA) forecasts appears to be the more appropriate way to reduce the estimation variability at the end of the sample.

Figure 4 Real time output gap estimations for the period 2004 Q1 – 2005 Q4

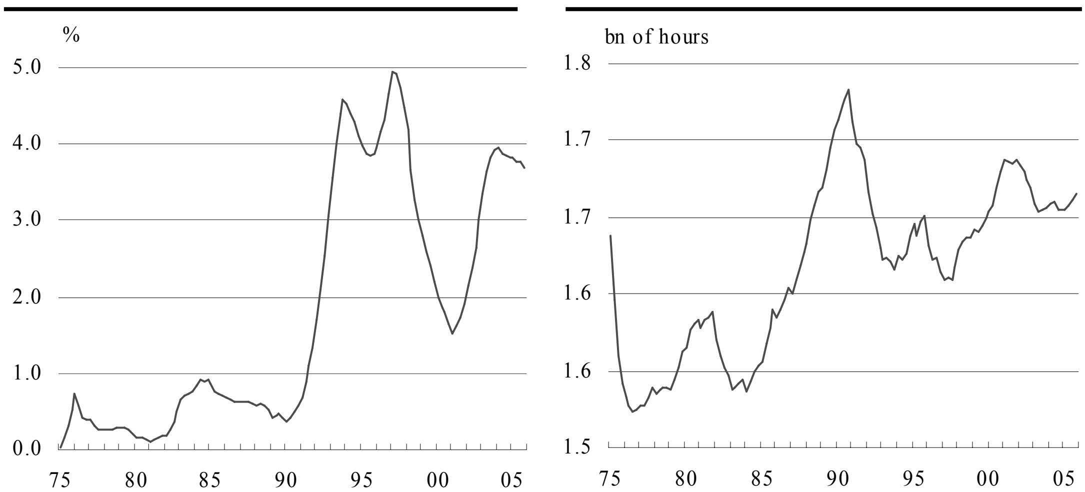
Chart 1 Method Bruchez (2001) | Chart 2 Method time series extension



We next compare the output gap estimations with those of the HP filter and the Laxton-Tetlow filter. For estimating the Laxton-Tetlow filter we use hours effectively worked in the Okun's law relationship, rather than the unemployment rate. As can be deduced from Chart 1 in Figure 5, the unemployment rate is not a good labour market indicator since it remained very low until 1990, irrespective of changing economic conditions. It was only after 1990 that the unemployment rate followed the business cycle. The number of hours effectively worked (Chart 2 of Figure 5), instead, seems to react more strongly to economic conditions.

Figure 5 Unemployment rate and hours effectively worked, 1975 Q1 – 2005 Q4

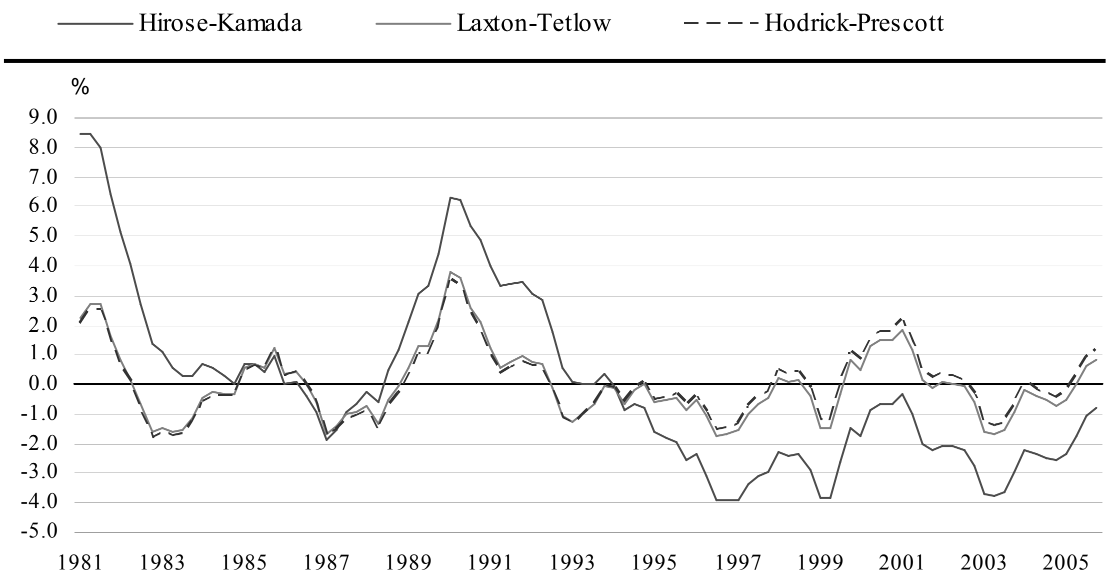
Chart 1 Unemployment rate | Chart 2 Hours effectively worked



According to the HP filter and the Laxton-Tetlow filter, potential annual growth averaged 2.1% in the 1980s and 1.2% during the 1990s. By contrast, the Hirose-Kamada filter points to higher growth rates, namely 2.6% in the 1980s and 1.7% in the 1990s. From 2000, the average annual growth rate of potential output is similar across the three filters and amounts to 1.1-1.2%.

The output gaps resulting from the three filters are depicted in Figure 6. A clear difference can be identified, starting in 1995, when the Hirose-Kamada filter clearly shows a larger negative output gap than the other two filters. Such differences may be critical for monetary policy. While both the Laxton-Tetlow filter and the HP filter suggested a more restrictive policy stance, no particular restrictive policy recommendation ensues from the Hirose-Kamada filter.[11]

Figure 6 A comparison of output gap estimates



[11] For the Laxton-Tetlow filter we set $\lambda_{y_t} = 1$ and $\lambda_{\pi_t} = \lambda_{U_t} = 2$. Thus, our results are broadly in line with those reported by the SNB in its Quarterly Bulletin, which are based on a slightly different specification. Furthermore, these weights are very similar to those used by the authors in their original article. As pointed out by Hirose and Kamada (2003, footnote 7, p. 97), setting $\lambda_{\pi_t} = 1$ and $\lambda_{y_t} = \lambda_{U_t} = 0$ in the Laxton-Tetlow filter one obtains the Hirose-Kamada filter as a special case. Hence, the difference between the two filters mainly resides in the choice of λ_{π_t}. For instance, by setting $\lambda_{y_t} = 1$, $\lambda_{\pi_t} = 30$ and $\lambda_{U_t} = 0$ the output gap estimations of the two filters are very similar (correlation coefficient of 0.99). This result underlines our criticism of the Laxton-Tetlow filter whose major drawback consists in choosing suitable values for the additional smoothing parameters.

4. Exchange rate pass-through

In the previous sections we assumed a Phillips curve in which inflation is only dependent on lagged inflation and the output gap. However, in a small open economy strongly integrated into the world economy, domestic inflation is not least influenced by the exchange rate. The exchange rate affects domestic inflation via two channels. In the first channel, import price changes have a direct effect on inflation. If, for instance, the domestic currency weakens, imported good prices rise. Since the basket forming the CPI contains imported goods, CPI inflation increases straight away. The second channel affects inflation more indirectly by switching consumption from foreign goods to domestic goods. If the domestic currency weakens, worldwide demand for domestic goods may increase relative to the demand for foreign goods, additionally boosting the price of domestic goods.

The percentage change in local prices resulting from a one percent change in the relative exchange rates of the exporting and importing countries is referred to as exchange rate pass-through (ERPT).[12] If a change in the exchange rate is completely (partially) reflected in domestic prices, ERPT is said to be complete (incomplete). In the traditional ERPT literature, microeconomic factors that are exogenous to domestic monetary policy basically determine the pass-through to import prices.[13] More recently, the emphasis has shifted, and researchers are now examining the extent to which import prices are passed through to domestic prices in conjunction with monetary policy. As argued by Taylor (2000), the pass-through to aggregate prices is primarily a function of the persistence of exchange rate and price shocks, both of which tend to be limited in a regime of low inflation and credible monetary policy. This hypothesis has been recently subject to intense theoretical research embedded in a new open-economy macroeconomics framework, in which ERPT is explicitly linked to the inflation environment.[14]

Empirical analysis has put forth three main results. First, a large body of literature covering several countries has documented that movements in the domestic currency are not fully mapped onto a proportional change in import prices. Second, although incomplete, the ERPT to imported goods is higher than the pass-through to consumer prices. Third, the ERPT to both import and consumer prices appears to have been declining over time in many countries, irrespective of large exchange rate depreciations. The decline in the degree of ERPT coincides with the transition to a low-inflation environment in the 1990s.

In Switzerland ERPT has been found to be very weak (cf. McCarthy, 2000; Choudhri and Hakura, 2001; Devereux and Yetman, 2002; Gagnon and Ihrig, 2004). At variance with the general findings, Campa and Goldberg (2005) document that Switzerland has one of the highest

[12] The traditional definition of ERPT is the percentage change in the local currency price of an imported good resulting from a 1 per cent change in the nominal exchange rate. Nowadays the definition includes other types of prices, such as producer prices and consumer prices.

[13] Goldberg and Knetter (1997) provide a comprehensive review of this literature.

[14] Cf., among others, Obstfeld and Rogoff (1995), Choudhri and Hakura (2001), Devereux and Yetman (2002) and Devereux et al. (2004).

elasticities of import prices in a sample of OECD countries. Stulz (2006), too, reports a substantial ERPT to import prices, but only very moderate effects to consumer prices. He also provides evidence of a decreasing ERPT in the 1990s.

We add to the literature on exchange rate movements onto Swiss consumer prices. To this end, we insert the exchange rate into the Phillips curve and estimate the size of ERPT effects jointly with the output gap, using the Hirose-Kamada filter. We start by defining the price index of a country as a geometric weighted average of domestic prices, P_t^D, and prices of imported goods, P_t^M:[15]

$$P_t \equiv P_t^{D(1-\gamma)} P_t^{M\gamma} \tag{10}$$

where γ is the share of foreign goods in the domestic CPI. The letter *D* denotes the domestic goods and *M* the imported goods. Inflation can consequently be written as:

$$\begin{aligned} \pi_t &= (1-\gamma)\pi_t^D + \gamma\pi_t^M \\ &= \pi_t^D + \gamma(\pi_t^M - \pi_t^D) \end{aligned} \tag{11}$$

The condition of complete ERPT is equivalent to:

$$P_t^M = P_t^W S_t \tag{12}$$

or

$$\pi_t^M = \pi_t^W + \Delta s_t \tag{13}$$

where P_t^W stands for the world price index and thus π_t^W for world inflation; S_t (s_t) represents the (logarithmic) exchange rate. Equation (13) indicates that a price increase abroad is reflected (*ceteris paribus*) in a par for par increase in imported goods.

Next, inserting (13) into (11) we obtain:

$$\begin{aligned} \pi_t &= \pi_t^D + \gamma(\pi_t^W + \Delta s_t - \pi_t^D) \\ &= \pi_t^D + \gamma\Delta q_t \end{aligned} \tag{14}$$

where q_t captures the real exchange rate.

Then, assuming that domestic inflation follows the process specified in equation (5):

$$\pi_t^D = a(L)\pi_{t-1}^D + \beta(y_t - y_t^p) + \varepsilon_t$$

we derive from (14)

$$\pi_t = a(L)\pi_{t-1}^D + \beta(y_t - y_t^p) + \gamma\Delta q_t + \varepsilon_t \tag{15}$$

Finally, by repeatedly inserting the relationship postulated in (14), we arrive at the Phillips curve underlying our ERPT estimations:

$$\pi_t = a(L)\pi_{t-1} + \beta(y_t - y_t^p) + \gamma(\Delta q_t - a(L)\Delta q_{t-1}) + \varepsilon_t \tag{16}$$

[15] The model is discussed in detail in Kara and Nelson (2002).

Equation (16) differs from the basic Phillips curve postulated so far, in that it includes the change in the real exchange rate as an additional exogenous variable. In this equation, the coefficients of the lagged real exchange rate are restricted to be proportional to the corresponding lagged inflation by $-\gamma$. Therefore the lag structure of the real exchange rate must be identical to the one chosen for the inflation rate. The hypothesis of a complete ERPT can be tested with the aid of γ which captures the share of foreign goods in the CPI, currently 25%. Thus for the ERPT to be complete, γ has to be equal to 0.25.[16] The real exchange rate is measured by the real export-weighted exchange rate index of the Swiss franc. The estimation results are presented in Table 2.

Table 2 Estimation results for the Phillips curve including the exchange rate, 1981 Q1 – 2005 Q4

variable		coefficient	*t*-statistics
constant		0.0015	3.1140
π_{t-1}	a_0	0.5866	7.1260
π_{t-2}	a_1	0.1302	1.2107
output gap$_t$	β	0.0749	2.2333
real exchange rate	γ	-0.0401	-2.3838
$\overline{R}^2 = 0.56$			n = 100

HAC *t*-statistics

The coefficient of the real exchange rate is significantly different from zero but small: the pass-through to consumer prices seems to be rather modest. Since Switzerland has enjoyed one of the lowest inflation rates in the world over the last 30 years, our result is thus in line with related empirical work, which finds that countries with lower and/or less volatile CPI inflation also tend to exhibit lower exchange rate pass-through effects.[17]

[16] As shown by Bacchetta and van Wincoop (2003), differing pricing strategies on the part of foreign wholesalers and domestic retailers can explain why pass-through to consumer prices may be lower than the share of imports in the consumption basket, even if pass-through to import prices is complete.

[17] Cf. Goldfajn and Werlang (2000), Choudhri and Hakura (2001), Gagnon and Ihrig (2004), Frankel et al. (2005) and Sekine (2006).

5. Conclusions

Various filters have been described for estimating potential output and thus the output gap. In this paper we focused on the multivariate filter evolved by Hirose and Kamada (2003). Being a multivariate filter, it combines the advantages of the univariate HP filter, such as its general applicability, with economic information. Univariate filters, being developed for the determination of the business cycle, are less suitable for estimating potential output and output gap, since they neglect the inflation path. By broadening the HP filter with a Phillips curve, the Hirose-Kamada filter takes explicit account of the information on the inflation rate. It also allows us to build confidence intervals to assess the uncertainty surrounding the estimations. Using Swiss data, we compare the results of the Hirose-Kamada filter with those of the HP filter and those of the multivariate Laxton-Tetlow filter. The results for the 1980s are fairly comparable across the three filters but diverge from the mid-1990s.

Besides lending itself to business cycle analysis, the Hirose-Kamada filter can also be used to estimate exchange rate pass-through effects. In keeping with related empirical analysis, exchange rate swings seem to have had only a moderate effect on consumer prices. This result is relevant in many respects. First, a low pass-through points to a weak expenditure-switching effect following swings in the exchange rate. Second, this evidence may be of interest for the Swiss National Bank's inflation forecasts, since it suggests that changes in the exchange rates have little effect on the future path of inflation. Third, if exchange rate pass-through rates are endogenous to a country's relative monetary stability, stable inflation may enhance the power of monetary policy to stabilise the economy.

Appendix

Bootstrap procedure for building confidence intervals

This appendix describes the procedure for building confidence intervals, as proposed by Hirose and Kamada (2003).

1. Estimate Phillips curve and potential output – or the output gap – according to the method described on p. 6 and store the residuals $\hat{\varepsilon}_t$ ($t = 1, \cdots, T$). The estimated coefficients and potential output are denoted by $\hat{a}_0, \cdots, \hat{a}_l, \hat{\beta}$ and $\hat{y}_t^p$.

2. Generate $t = 1, \cdots, T$ bootstrap errors $\tilde{\varepsilon}_t$ based on the residuals $\hat{\varepsilon}_t$.

3. Generate simulated inflation rates $\tilde{\pi}_t$ based on

$$\tilde{\pi}_t = \hat{a}(L)\tilde{\pi}_{t-1} + \hat{\beta}(y_t - \hat{y}_t^p) + \tilde{\varepsilon}_t$$

4. Repeat the iterative procedure presented on p. 6 based on the new calculated time series $\tilde{\pi}_t$.

   a. Estimate the Phillips curve $\tilde{\pi}_t = a(L)\tilde{\pi}_{t-1} + \beta(y_t - \hat{y}_t^p) + \varepsilon_t$ by OLS and denote the new estimated coefficients by $\hat{a}_0^*, \cdots, \hat{a}_l^*, \hat{\beta}^*$.

   b. Calculate the variable $\tilde{z}_t = y_t - \dfrac{\left(\tilde{\pi}_t - \hat{a}^*(L)\tilde{\pi}_{t-1}\right)}{\hat{\beta}^*}$.

   c. Apply the HP filter to $\tilde{z}_t$ and obtain the new estimate for potential output $\tilde{y}_t^{p^*}$.

   d. Return to a. and substitute $\hat{y}_t^p$ with $\tilde{y}_t^{p^*}$.

   e. Repeat a. to c. as long as the coefficients $\hat{a}_0^*, \cdots, \hat{a}_l^*, \hat{\beta}^*$ change from one iteration to the next. At the end of the iteration, store the estimate of potential output $\tilde{y}_t^{p^*}$. This time series is a realisation of the bootstrap procedure.

5. Repeat steps 2 to 4 *n* times to obtain *n* estimations of potential output $\tilde{y}_t^{p^*}$. Sort all the estimations in ascending/descending order and select those that build the $(\alpha\%, (1-\alpha\%))$ confidence interval.

Data description

Real gross domestic product (GDP): Quarterly real GDP estimation in millions of Swiss francs. Source: seco

Consumer price index (CPI): Index of consumer prices (all goods). Source: Swiss Federal Statistical Office.

Hours effectively worked: Number of hours effectively worked. Source: Swiss National Bank (available upon request).

Real export-weighted exchange rate of the Swiss franc: Index. Source: Swiss National Bank

Unit Root Tests

Table A1 Unit Root Tests for the inflation series 1981 Q1 – 2005 Q4

	ADF	KPSS	ERS	Ng-Perron			
				MZa	MZt	MSB	MPT
Constant	-4.0312	0.6189	21.0691	-1.4071	-0.7171	0.5096	14.5905
	(-2.8906)	(0.4630)	(3.1100)	(-8.1000)	(-1.9800)	(0.2330)	(3.1700)
Constant and trend	-4.8104	0.0697	14.3571	-7.6074	-1.8907	0.2485	12.1216
	(-3.4554)	(0.1460)	(5.6400)	(-17.3000)	(-2.9100)	(0.1680)	(5.4800)

Note: ADF: Augmented Dickey-Fuller Test; KPSS: Kwiatkowski-Phillips-Schmidt-Shin Test; ERS: Elliott-Rothenberg-Stock Test; Ng-Perron Tests: MZa, MZt, MSB, MPT: Modified version of the Phillips and Phillips-Perron, Bhargava and Elliott-Rothenberg-Stock tests based on GLS detrending and modified AIC criterium. In brackets the critical values at 5% confidence level.

Residuals distribution

Figure A1 Analysis of residuals

Chart 1 Normal plot

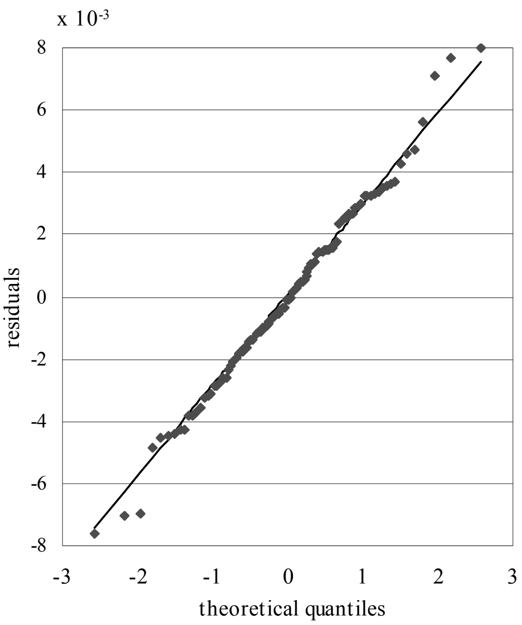
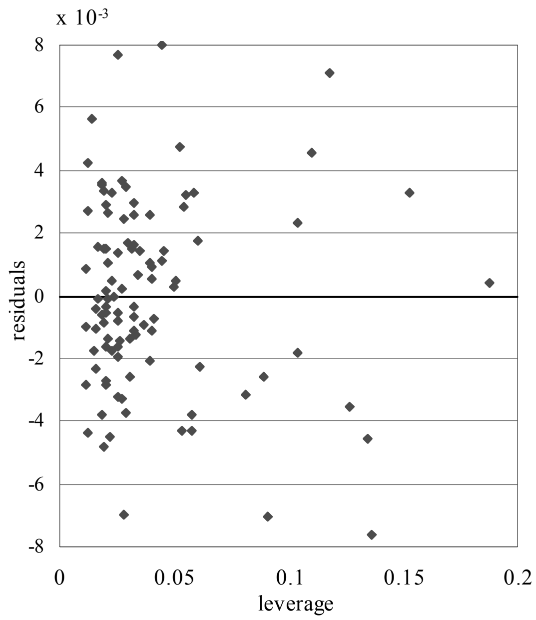


Chart 2 Leverage-residual plot



References

Bacchetta, Philippe and Eric van Wincoop. 2003. Why do consumer prices react less than import prices to exchange rates? *Journal of the European Economic Association* (2-3): 662-670.

Bruchez, P.-A. 2003. A modification of the HP filter aiming at reducing the end-point bias. Swiss Federal Finance Administration Working Paper No. ÖT/2003/3, August.

Campa, José Manuel and Linda S. Goldberg. 2005. Exchange rate pass-through into import prices. *Review of Economics and Statistics* 87(4): 679-690.

Choudhri, Ehsan U. and Dalia S. Hakura. 2001. Exchange rate pass-through to domestic prices: Does the inflationary environment matter? IMF Working Paper 01/194, December.

Cogley, Timothy and James M. Nason. 1995. Effects of the Hodrick-Prescott filter on trend and difference stationary time series: Implications for business cycle research. *Journal of Economic Dynamics and Control* 19(1-2): 253-278.

Conway, Paul and Ben Hunt. 1997. Estimating potential output: A semi-structural approach. Reserve Bank of New Zealand Discussion Paper G97/9.

Devereux, Michael B. and James Yetman. 2002. Price setting and exchange rate pass-through: Theory and evidence. In *Price Adjustment and Monetary Policy*. Proceedings of a conference held at the Bank of Canada, November 2002. Ottawa: Bank of Canada.

Devereux, Michael B., Charles Engel and Peter E. Storgaard. 2004. Endogenous exchange rate pass-through when nominal prices are set in advance. *Journal of International Economics* 63(2): 263-291.

Efron, Bradley and Robert J. Tibshirani. 1993. *An introduction to the bootstrap*. New York, NY: Chapman & Hall.

Frankel, Jeffrey. A., David C. Parsley and Shang-Jin Wei. 2005. Slow passthrough around the world: A new import for developing countries? NBER Working Paper No. 11199.

Gagnon Joseph E. and Jane Ihrig. 2004. Monetary policy and exchange rate pass-through. *International Journal of Finance and Economics* 9: 315-338.

Goldberg, Pinelopi Koujianou and Michael M. Knetter. 1997. Goods prices and exchange rates: What have we learned? *Journal of Economic Literature* 35(3): 1243-1272.

Goldfajn, Ilan and Sergio R. da C. Werlang. 2000. The pass-through from depreciation to inflation: A panel study. Banco Central de Brasil Working Paper Series No. 5, July.

Guay, Alain and Pierre St-Amant. 1996. Do mechanical filters provide a good approximation of business cycles? Bank of Canada Technical Report 78.

Haltmaier, Jane T. 1996. Inflation-adjusted potential output. Board of Governors of the Federal Reserve System. International Finance Discussion Papers No. 561, August.

Harvey, Andrew C. 1989. *Forecasting, structural time series and the Kalman filter*. Cambridge UK, Cambridge University Press.

Harvey, A.C. and A. Jaeger. 1993. Detrending, stylized facts and the business cycle. *Journal of Applied Econometrics* 8(3): 231-247.

Hirose, Yasuo and Koichiro Kamada. 2003. A new technique for simultaneous estimation of potential output and the Phillips curve. Bank of Japan *Monetary and Economics Studies*: 93-112.

Hodrick, Robert J., and Edward C. Prescott. 1997. Postwar U.S. business cycles: An empirical investigation. *Journal of Money, Credit and Banking* 29(1): 1-16.

Kaiser, Regina and Agustin Maravall. 2001. *Measuring business cycles in economic time series.* Lecture Notes in Statistics, Springer.

Kara, Amit and Edward Nelson. 2002. The exchange rate and inflation in the UK. Bank of England External MPC Unit Discussion Paper No. 11.

King, Robert G. and Sergio T. Rebelo. 1993. Low frequency filtering and real business cycles. *Journal of Economic Dynamics and Control* 17: 207-231.

Laxton, Douglas and Robert Tetlow. 1992. A simple multivariate filter for the measurement of potential output. Bank of Canada Technical Report 59.

McCarthy, Jonathan. 2000. Pass-through of exchange rates and import prices to domestic inflation in some industrialized economies. Federal Reserve Bank of New York Staff Report 111.

Mills, Terence C. 2003. *Modelling trends and cycles in economic time series*. Palgrave Texts in Econometrics. Houndmills, U.K. and New York: Palgrave Macmillan.

Ng, Serena and Pierre Perron. 2001. Lag length selection and the construction of unit root tests with good size and power. *Econometrica* 69(6): 1519-1554.

Obstfeld, Maurice and Kenneth Rogoff. 1995. Exchange rate dynamics redux. *Journal of Political Economy* 103(3): 624-660.

Politis, Dimitris N. and Joseph P. Romano. 1994. The stationary bootstrap. *Journal of the American Statistical Association* 89: 1303-1313.

Politis, Dimitris N. and Halbert White. 2003. Automatic block-length selection for the dependent bootstrap. University of California Working Paper, San Diego. February

Rudolf, Barbara. 2001. Methoden zur Schätzung des Produktionspotenzials. Schweizerische Nationalbank Konjunktur und Preise, Internes Papier. Februar: 40-41.

Sekine, Toshitaka. 2006. Time-varying exchange rate pass-through: Experiences of some industrial countries. BIS Working Papers No 202, March.

St-Amant, Pierre and Simon van Norden. 1997. Measurement of the output gap: A discussion of recent research at the Bank of Canada. Bank of Canada Technical Report 79, August.

Stulz, Jonas. 2006. Exchange rate pass-through in Switzerland: Evidence from vector autoregressions, mimeo.

Taylor, John B. 2000. Low inflation, pass-through, and the pricing power of firms. *European Economic Review* 44: 1389-1408.

Swiss National Bank Working Papers published since 2004:

2004-1 Samuel Reynard: Financial Market Participation and the Apparent Instability of Money Demand

2004-2 Urs W. Birchler and Diana Hancock: What Does the Yield on Subordinated Bank Debt Measure?

2005-1 Hasan Bakhshi, Hashmat Khan and Barbara Rudolf: The Phillips curve under state-dependent pricing

2005-2 Andreas M. Fischer: On the Inadequacy of Newswire Reports for Empirical Research on Foreign Exchange Interventions

2006-1 Andreas M. Fischer: Measuring Income Elasticity for Swiss Money Demand: What do the Cantons say about Financial Innovation?

2006-2 Charlotte Christiansen and Angelo Ranaldo: Realized Bond-Stock Correlation: Macroeconomic Announcement Effects

2006-3 Martin Brown and Christian Zehnder: Credit Reporting, Relationship Banking, and Loan Repayment

2006-4 Hansjörg Lehmann and Michael Manz: The Exposure of Swiss Banks to Macroeconomic Shocks – an Empirical Investigation

2006-5 Katrin Assenmacher-Wesche and Stefan Gerlach: Money Growth, Output Gaps and Inflation at Low and High Frequency: Spectral Estimates for Switzerland

2006-6 Marlene Amstad and Andreas M. Fischer: Time-Varying Pass-Through from Import Prices to Consumer Prices: Evidence from an Event Study with Real-Time Data

2006-7 Samuel Reynard: Money and the Great Disinflation

2006-8 Urs W. Birchler and Matteo Facchinetti: Can bank supervisors rely on market data? A critical assessment from a Swiss perspective

2006-9 Petra Gerlach-Kristen: A Two-Pillar Phillips Curve for Switzerland

2006-10 Kevin J. Fox and Mathias Zurlinden: On Understanding Sources of Growth and Output Gaps for Switzerland

2006-11 Angelo Ranaldo: Intraday Market Dynamics Around Public Information Arrivals

2007-1 Andreas M. Fischer, Gulzina Isakova and Ulan Termechikov: Do FX traders in Bishkek have similar perceptions to their London colleagues? Survey evidence of market practitioners' views

2007-2 Ibrahim Chowdhury and Andreas Schabert: Federal Reserve Policy viewed through a Money Supply Lens

2007-3 Angelo Ranaldo: Segmentation and Time-of-Day Patterns in Foreign Exchange Markets

2007-4 Jürg M. Blum: Why 'Basel II' May Need a Leverage Ratio Restriction

2007-5 Samuel Reynard: Maintaining Low Inflation: Money, Interest Rates, and Policy Stance

2007-6 Rina Rosenblatt-Wisch: Loss Aversion in Aggregate Macroeconomic Time Series

2007-7 Martin Brown, Maria Rueda Maurer, Tamara Pak and Nurlanbek Tynaev: Banking Sector Reform and Interest Rates in Transition Economies: Bank-Level Evidence from Kyrgyzstan

2007-8 Hans-Jürg Büttler: An Orthogonal Polynomial Approach to Estimate the Term Structure of Interest Rates

2007-9 Raphael Auer: The Colonial Origins Of Comparative Development: Comment. A Solution to the Settler Mortality Debate

2007-10 Franziska Bignasca and Enzo Rossi: Applying the Hirose-Kamada filter to Swiss data: Output gap and exchange rate pass-through estimates

Swiss National Bank Working Papers are also available at www.snb.ch, section Publications/Research
Subscriptions or individual issues can be ordered at Swiss National Bank, Fraumünsterstrasse 8, CH-8022 Zurich,
fax +41 44 631 81 14, E-mail library@snb.ch