A Two-Pillar Phillips Curve for Switzerland

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Abstract

Historically, money growth has played an important role in Swiss monetary policy, until 1999 as a target and from 2000 onwards as an indicator variable. Since the new policy framework focusses on an inflation forecast, the question arises how useful money growth is for predicting future price developments. Using Swiss data, this paper estimates a model first proposed by Gerlach [13] for the euro area that integrates money growth in an inflation forecasting equation. This "two-pillar" Phillips curve suggests that the low-frequency component of money growth, alongside current inflation and the output gap, helps predict future inflation. These results are confirmed by an alternative money-augmented Phillips curve proposed by Neumann [24].

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1 Introduction

While there is general agreement that, as Friedman and Schwartz [11] put it, inflation is a monetary phenomenon and while empirical evidence in high-inflation countries supports this notion, it has been argued that money growth is not a useful predictor of changes in the price level in economies with low inflation.[1] As a consequence, the importance attached to money in setting interest rates differs between central banks. Two monetary authorities that use information obtained from monetary aggregates in their policy decisions are the European Central Bank (ECB) and the Swiss National Bank (SNB).

From the collapse of the Bretton Woods system until the end of 1999 monetary policy in Switzerland was guided by growth targets for monetary aggregates.[2] Since 2000 the SNB has aimed to maintain price stability, defined as an annual rate of increase of the consumer price index of under two percent. Policy decisions draw on formal model-based forecasts of inflation as well as on two sets of indicators that are informative about future price developments. Jordan, Peytrignet and Rich [17] describe the first set as variables "useful for forecasting short-run price developments", such as the output gap, labour market data and the real exchange rate, and the second set as comprising information from monetary aggregates, in particular from M3, which the SNB sees as "provid[ing] useful leading information on long-run price developments" (SNB [29]).

The ECB's policy strategy relies on a "two-pillar" framework to keep the rate of increase of the harmonised index of consumer prices below two percent. The ECB's first Monthly Bulletin [8] reviews its monetary policy strategy in detail.[3] The first pillar assigns money "a prominent role", where M3 growth of 4.5% per year is seen compatible with price stability, but where deviations from this reference value do not trigger automatic policy responses. The second pillar combines information regarding future price developments extracted from "a wide range of economic and financial variables". In its review of the monetary policy strategy published in 2003, the ECB specifies that the second pillar is useful for judging the impact of demand and supply factors on inflation in the short run,

[1] See e.g. de Grauwe and Polan [5]. However, Nelson [23] challenges their analysis.
[2] Peytrignet [26] and Rich [28] provide detailed discussions of Swiss monetary policy before 2000.
[3] See also ECB [6] and [7].

while the first pillar provides insights with respect to inflation in the medium to long run (ECB [9]). The ECB's and the SNB's policy strategies thus share the feature that monetary and real factors enter the inflation analysis separately and the view that the former help explain inflation in the long run and the latter in the short run. In contrast to the ECB, the SNB does not specify a reference value for the growth rate of M3.[4]

The ECB's policy strategy has been criticised since money growth, in spite of its prominent position as a separate pillar, does not seem to matter for future inflation in the euro area (see e.g. Begg, Canova, De Grauwe, Fatas and Lane [2]). Gerlach [13], however, proposes a "two-pillar" Phillips curve model in which inflation depends on a filtered measure of money growth, which extracts the low-frequency component of changes in M3 and which he interprets as a representation of the first pillar, and on the output gap, which he views as a summary measure for the "wide range of economic and financial variables". He finds that filtered rather than actual money growth impacts on future inflation, which suggests that persistent movements in money matter more for prices than temporary changes.

This paper starts by demonstrating that actual money growth also is insignificant in a simple Phillips curve for Switzerland. Thus, the SNB's policy framework in principle is exposed to the same criticism as the ECB's. We then go on to show that filtered money growth helps forecast inflation and to estimate the two-pillar Phillips curve, which fits the data well. This supports the notion that in the long run money predicts prices in Switzerland, which implies that Gerlach's results have broader validity than just for the euro area.

Several other contributions to the literature are made. First, the results show that M3 growth is more clearly linked to future inflation than M2 growth. This may be due to the higher interest rate sensitivity of M2, which is not captured by the Phillips curve and which may limit the effect of M2 movements on inflation. Second, we discuss how to handle the revision in the Swiss consumer price index (CPI) in May 2000, which caused an increase in the volatility of inflation. Our proposed approach is a simple statistical

[4]Jordan, Peytrignet and Rich [17] argue that the SNB's difficulties in reaching its money growth targets before 2000 rendered a numerical reference value unattractive.

technique that yields plausible adjustments in the inflation series. Needless to say, this is not a substitute for a thorough analysis of the changes in the computation of the CPI. Third, we confirm the finding that money matters by estimating a version of the Phillips curve proposed by Neumann [24] that uses a slightly different low-frequency measure of money growth than Gerlach.

The rest of the paper is structured as follows. Section 2 reviews the literature on inflation forecasting equations for Switzerland. There are relatively few papers on the Swiss Phillips curve, only one of which includes money, but several authors have estimated inflation forecasting equations in connection with models that involve money. Section 3 presents the data used in the analysis. Since the computation of CPI inflation was revised in 2000, we devote special attention to the resulting change in the time-series behaviour of inflation and propose an adjustment of certain component series of the CPI. Section 4 discusses some preliminary evidence on the link between money growth and inflation in Switzerland. We find that while the output gap forecasts inflation only at a short horizon, a filtered version of money growth seems a useful predictor of inflation also several years ahead. Section 5 estimates a standard Phillips curve that includes actual money growth and then discusses and fits the two-pillar model, which uses a low-frequency component of money growth. Section 6 provides a sensitivity analysis of the two-pillar model by estimating the alternative money-augmented Phillips curve suggested by Neumann [24]. We find that also this model helps forecast inflation in Switzerland. Section 7 concludes.

2 Literature

Traditional empirical Phillips curves link the rate of inflation to past economic activity and frequently to lagged inflation. High activity, as measured by either low unemployment or a large output gap, is thought to increase future inflation. More recently, forward-looking Phillips curves have been proposed that include expected future inflation, and empirical evidence has been provided for models that combine forward and backward-looking elements (e.g. Fuhrer and Moore [12]). Typically, it is found that the coefficients on future and past inflation sum to close to unity.

Several authors have estimated Phillips curves for Switzerland. Zanetti [32], in a study on the Swiss NAIRU, uses unemployment as a measure of activity and finds that it has a significant impact on inflation in a backward-looking Phillips curve over the period 1978 to 1997. Lüscher [22] estimates a Phillips curve that combines forward and backward-looking elements for the years 1978 to 1993 and finds that lagged inflation, inflation expectations from a consumer survey and the output gap are significant predictors of future price movements. The focus of that paper is on non-linearities in the Phillips curve, which seem present and for which Wyplosz [31] provides further evidence. He considers data for four European countries spanning 1962 to 1999 and shows that inflation in Switzerland depends on its own past value, import price inflation, unemployment and inflation expectations as proxied by the difference between a long-term bond yield and a measure of the world real interest rate. Laubach and Posen [21] examine in a data set of eight industrial countries whether the introduction of an inflation target alters the reaction of inflation to real economic variables. Switzerland is used as a control country and its Phillips curve is estimated on data from 1971 to 1990 and includes as significant variables lagged inflation, the output gap and the nominal effective exchange rage.

Phillips curves also play an important role in two models used in the inflation forecasting process of the SNB, which are referred to as the large and the small macro model (see Jordan and Peytrignet [16] for an overview of the different models in use). In the large macro model inflation depends in the long run on the deviation of nominal aggregate demand from real potential and thus on money growth, whereas it is driven by real factors in the short run (see also Stalder [30]). In the basic version of the small macro model, the Phillips curve includes the output gap, past inflation and the exchange rate, whereas in the more general version M3 growth enters.[5] The forecasting performance of the Phillips curve over one to three years ahead is markedly improved by this inclusion (see Zurlinden [33]).

A number of authors have studied the impact of money on inflation in Switzerland without using to the concept of the Phillips curve. Baltensperger, Jordan and Savioz [1] consider inflation equations that comprise money growth and the difference between actual

[5] The model uses a six-month moving average of M3 growth lagged by three years.

and equilibrium money demand. Using data spanning 1978 to 1999, they find that both the growth rate of money and the deviation of money demand from equilibrium impact on annual inflation one to three years ahead and on cumulative inflation over the same horizons. Jordan, Peytrignet and Rich [17] estimate a similar model for the years 1975 to 2000 and show that M3 growth forecasts inflation well over long horizons while money in excess of equilibrium demand predicts price movements up to three years. Peytrignet and Stahel [27] study a vector error correction model for Switzerland and present an inflation equation for the period 1977 to 1997 that includes as significant variables the growth rate of real GDP, the German inflation rate and the deviation of M3 from long-run money demand.[6] Jordan and Savioz [18] discuss a number of unrestricted VARs for the period 1974 to 2000 that include consumer price inflation, the growth rates of M3, real GDP and loans as well as the change in long-run interest rates. They show that models that consider money seem to perform well over forecast horizons spanning one to three years. Kugler and Jordan [20], finally, present a structural VAR that includes consumer price inflation, the growth rates of real GDP and M1 and the change in the three-month interest rate. Using data spanning 1974 to 2002, they demonstrate that money growth impacts on inflation.

Overall, there is considerable evidence that money growth contains information useful to forecast inflation in Switzerland. However, these results stem from inflation equations that are not based on a Phillips curve. Below we follow Gerlach [13] and show that while money growth per se tends to be insignificant in the Phillips curve, a more slowly evolving filtered version thereof is a useful indicator of future inflation.

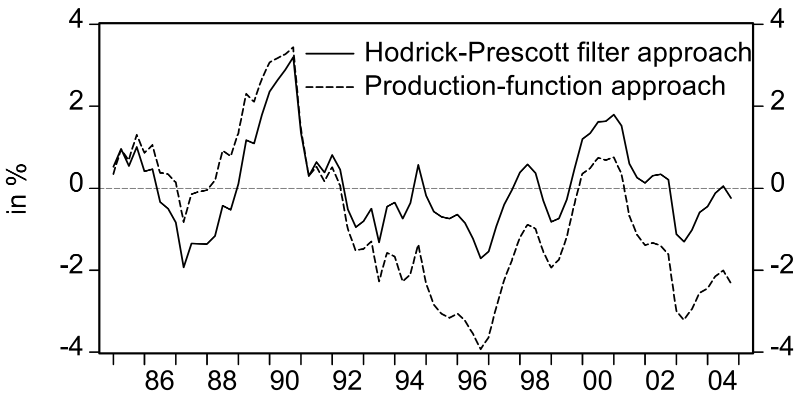
[6] It should be noted that in these papers inflation is assumed to be driven by the rather volatile deviation of money from its long-term trend, whereas in the two-pillar model below it is a smoothed version of money growth that impacts on inflation.

3 Data

3.1 The output gap

We use quarterly data for 1985:1 to 2005:1 in the estimation below. Figure 1 shows the output gap g_t, which is given by the difference between the logarithm of real GDP, Y_t, and its Hodrick-Prescott filtered counterpart, $\overline{Y}_t$, together with an SNB internal measure that is based on a production-function approach.[7] The two series display a correlation of 0.80 and thus largely contain the same information. Indeed, while we focus on the Hodrick-Prescott measure below, the conclusions of the paper do not depend on the choice of the output gap series.

Figure 1: Output gap data



Note: 1985:1 to 2005:1. The output gap based on the Hodrick-Prescott filter is computed using a smoothing parameter 1600. The production-function output gap is an internal SNB series.

3.2 Money growth

Both Gerlach [13] and Neumann [24] use M3 as their measure of money, presumably because the ECB's reference value concerns the growth rate of that monetary aggregate. However, it is a priori not clear whether the growth rate μ_t of M2 or M3 is better able to forecast future inflation. While the last money growth targets used by the SNB up

[7] We set the smoothing parameter in the Hodrick-Prescott filter equal to 1600.

to the end of 1999 were set in terms of M3 growth, Fischer and Peytrignet [10] show that this variable was a poor predictor for inflation until the end-1980s. Rich [28] writes that it became useful only thereafter. We therefore consider M2 and M3 growth in the analysis.[8] Figure 2 shows the deseasonalised and annualised quarterly growth series of these two aggregates. We also plot a measure of trend money growth $\widetilde{\mu}_t$, which we compute following Gerlach [13] using a one-sided exponential filter as

$$\widetilde{\mu}_t = \lambda \mu_t + (1 - \lambda)\widetilde{\mu}_{t-1}. \tag{1}$$

Trend money growth thus is a weighted average of current money growth and past trend growth, where the parameter λ determines the weight on current money growth.[9] As Gerlach, we initially set $\lambda = 0.075$, which implies that a one-unit shock to μ_t triggers a 0.5 unit reaction in $\widetilde{\mu}_t$ after $\log(2)/\lambda = 9.2$ quarters. In the final version of the two-pillar Phillips curve below, λ is estimated.

We find that M2 growth is more volatile than M3 growth. The reason for this is that M2 responds if consumers shift from e.g. cash holdings to time deposits. M3, by contrast, includes all forms of deposits and therefore is not affected by such substitutions. The resulting difference in interest rate sensitivity is reflected in comparatively low correlations between M2 and M3 growth. The two measures of μ_t have a correlation of 0.60, and their trend series have a correlation of only 0.21. This suggests that the estimation of the two-pillar Phillips curve might be sensitive to the choice of monetary aggregate.

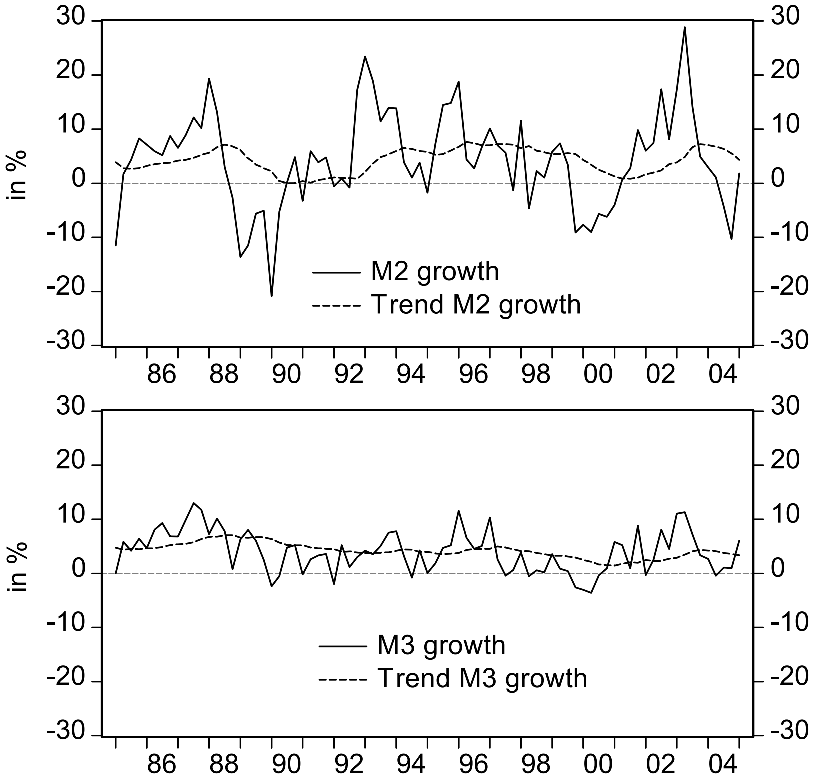
3.3 Inflation

For inflation, π_t, we consider CPI inflation, adjusted CPI inflation and core inflation. Core inflation is a trimmed mean of CPI inflation that excludes the top and bottom 15 percent of price movements. While central banks typically define their understanding of

[8] Jordan, Kugler, Lenz and Savioz [15] present Granger causality tests in which M1, M2 and M3 cause future inflation in Switzerland. Peytrignet and Stahel [27] argue that M3 is more useful than M2 in forecasting inflation.

[9] Cogley [4] proposes this filter to obtain a measure of core inflation. For analyses that use a frequency-domain approach to study the link between money growth and inflation see Bruggeman, Camba-Méndez, Fischer and Sousa [3] and Jaeger [14].

Figure 2: Money growth data



Note: 1985:1 to 2005:1. Deseasonalised annualised quarterly growth rates of M2 and M3. Trend growth rates are computed setting $\lambda = 0.075$ in equation (1).

price stability in terms of consumer prices, it has been widely suggested that monetary policy should focus on core inflation so as to avoid reacting to movements in highly volatile categories such as e.g. food prices. A further advantage of core inflation measures is that they tend to be relatively robust against changes in the computation of the CPI. This is an issue for Swiss CPI data because of a revision in the index that took place in May 2000.

Figure 3 shows the components of the CPI, which are available from the end of 1982 onwards. While the revision did not visibly affect the time-series behaviour of the majority of the index components, the pattern of two categories, "clothes and shoes" and "leisure and culture", changed.[10] While the clothes series was smooth up to the revision, it is very volatile and displays negative first-order correlation thereafter. The reason for this is that sales prices were taken into account after, but not before 2000. The leisure component of the CPI, by contrast, displays seasonal variation up to May 2000 and then becomes less volatile.

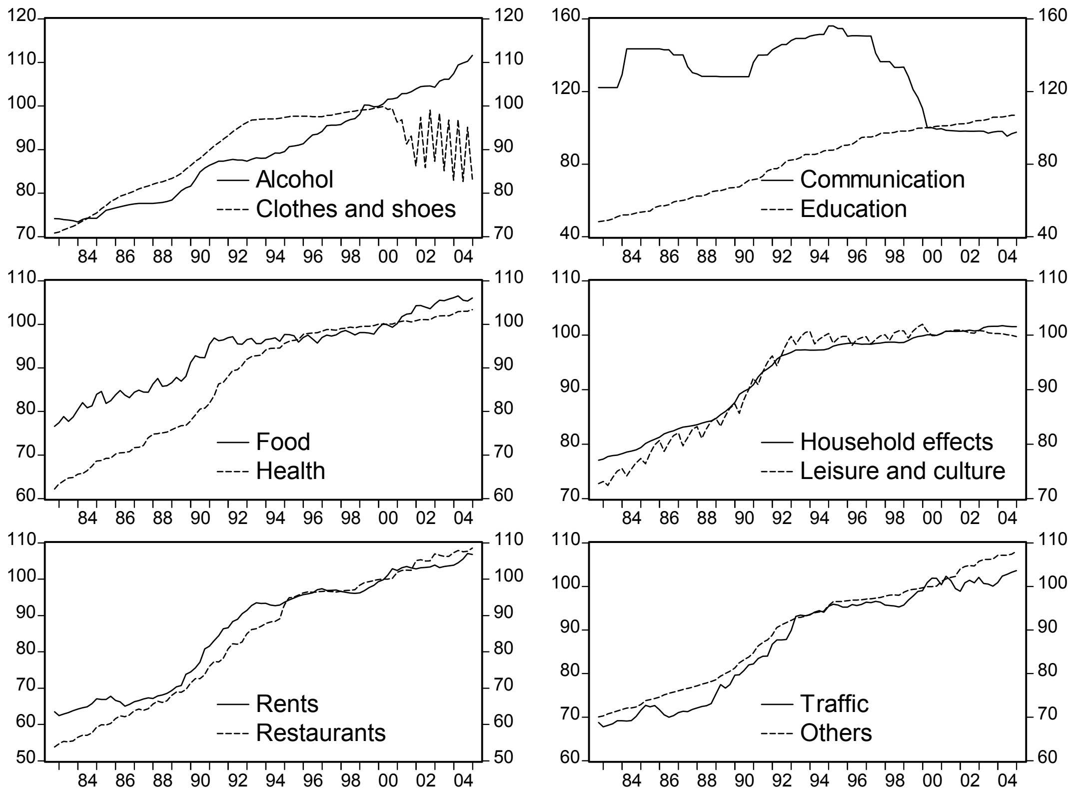
In estimation it is desirable to take into account that any change in volatility of CPI inflation around 2000 is probably not due to a fundamental change in the price formation mechanism in Switzerland. We therefore next construct an adjusted CPI series that "corrects" the clothes and leisure data. It should be emphasised that we use a simple statistical approach that is no substitute for careful analysis of the underlying changes.

To adjust the time series on clothes and leisure prices, we follow a state-space approach. In particular, we assume for the clothes component that up to the second quarter of 2000, the price level P_t equaled the state variable Z_t, which we let follow a random walk with drift. Thereafter, we define P_t as the sum of Z_t and an innovation X_t. To capture the fact that after the revision in the CPI index, clothes prices began to display a seasonal pattern, we assume for this component that X_t follows an AR(3) thereafter. Formally, we have that

$$P_t = \begin{cases} Z_t & \text{until 2000:2} \\ Z_t + X_t & \text{after 2000:2} \end{cases}, \tag{2}$$

[10]There also seems to have been a change in the behaviour of prices for communication. However, since that component has a weight of less than three percent in the CPI and since the change was not away from or towards a seasonal pattern, we do not model it here.

Figure 3: All CPI components



Note: 1982:4 to 2005:1. Price levels of CPI components.

$$Z_t = \begin{cases} A + \ Z_{t-1} + E_t & \text{until 2000:2} \\ A + \ Z_{t-1} + U_t & \text{after 2000:2} \end{cases} \tag{3}$$

and

$$X_t = BX_{t-1} + CX_{t-2} + DX_{t-3} + V_t, \tag{4}$$

with E_t, U_t and V_t white noise with variances σ_E^2, σ_U^2 and σ_V^2, respectively. It should be noted that besides introducing additional dynamics after 2000:2 via X_t, we also allow for a change in the size of the shocks affecting Z_t.

Treating equation (2) as the observation and equations (3) and (4) as the state equations, we apply maximum likelihood estimation to fit this model for the clothes component of the CPI using data spanning 1983:1 to 2005:1. The estimation output is presented in Table 1, and the adjusted clothes price series, which is the smoothed estimate of Z_t, is plotted in Figure 4. The table and graph also show the analysis for the leisure component of the CPI. To adjust the price series for leisure, we modify equation (2) to

$$P_t = \begin{cases} Z_t + X_t & \text{until 2000:2} \\ Z_t & \text{after 2000:2} \end{cases} . \tag{5}$$

Hence, leisure prices follow a random walk throughout the sample and are subject to AR(3) innovations up to 2000:2. We find that the AR parameters are highly significant for both the clothes and leisure models and that the variances of E_t and U_t and thus the size of the shocks affecting Z_t differed before and after the change in the CPI computation.

In the construction of the CPI, prices for leisure activities have at the time of writing a weight of 9.29%, while clothes prices account for 4.81% of the CPI. Since clothes prices after 2000:2 are much more volatile than leisure prices before that date, the adjustment in the CPI is larger after May 2000 than before. The upper plot of Figure 5 shows actual and adjusted quarterly CPI inflation for the period 1999:1 to 2005:1, where we obtain the adjusted CPI by replacing the actual price indices for clothes and leisure with their adjusted counterpart.[11] While the upper plot suggests rather large differences between the quarterly CPI series, it is important to note that the adjustment has a less dramatic

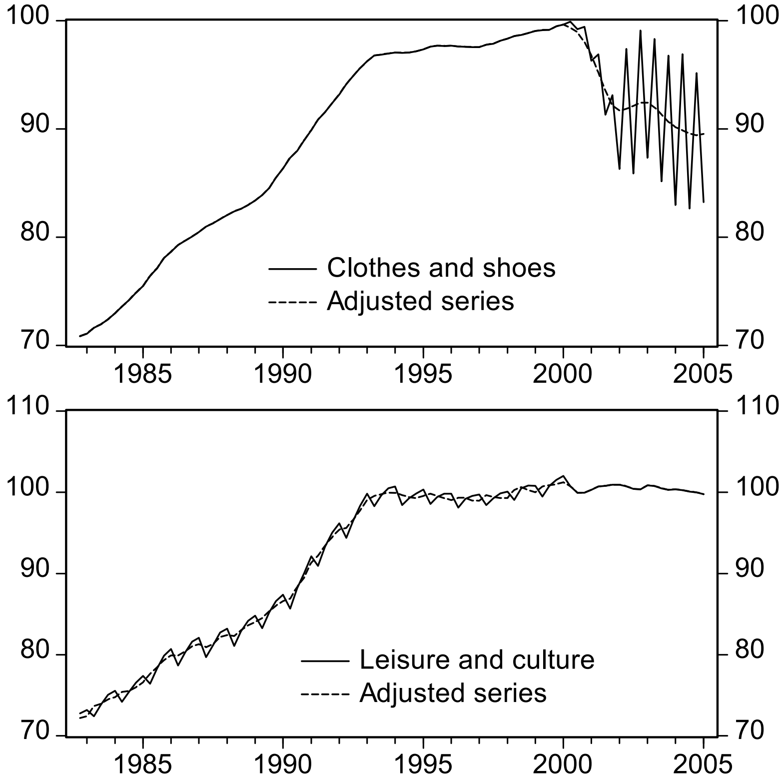
[11] Since the weights used for constructing the CPI vary over time and are not available for certain subperiods, we obtain the weights for the adjusted CPI by regressing the actual CPI on its components.

Table 1: State space estimates for
equations (2), (3) and (4) for clothes and shoes
equations (3), (4) and (5) for leisure and culture

CPI component	*Clothes and shoes*	*Leisure and culture*
observation equation	(2)	(5)
state equations	(3) and (4)	(3) and (4)
A	0.410***	0.351***
	(0.040)	(0.065)
B	-0.772***	-0.999***
	(0.232)	(0.013)
C	1.327***	-0.988***
	(0.309)	(0.010)
D	1.127**	-0.985***
	(0.450)	(0.017)
σ_E^2	0.096	0.412
σ_U^2	2.708	0.250
σ_V^2	0.226	0.000
loglik	-78.373	-111.765

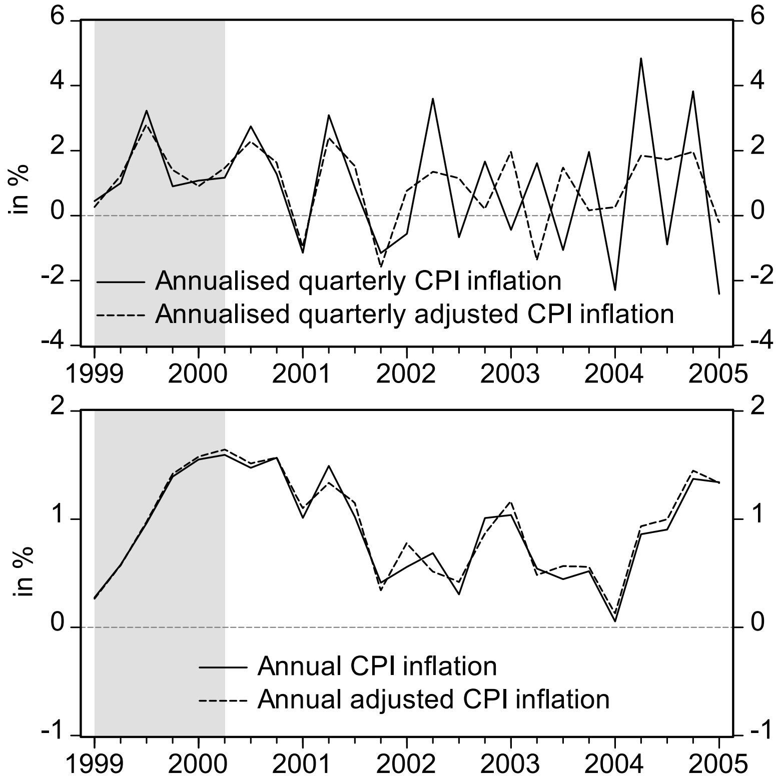
Note: State-space estimates, 1983:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level.

Figure 4: Actual and adjusted CPI components



Note: 1982:4 to 2005:1. Actual and adjusted price levels of the clothes and shoes and the leisure and culture components of the CPI.

Figure 5: Actual and adjusted CPI inflation



Note: 1999:1 to 2005:1. Actual and adjusted deseasonalised CPI inflation. The upper plot shows quarterly, the lower annual inflation. The shaded area marks the period before the index revision in May 2000.

effect if we consider annual CPI changes, as is visible in the lower plot in the figure. While from a statistical point of view it could be argued that the adjusted CPI is preferable to the actual CPI since it handles the measurement issues introduced by the May 2000 revision, we nevertheless present below estimations involving both series since actual CPI inflation is the measure monetary policy in Switzerland focusses on. Figure 6 shows actual and adjusted CPI inflation and core inflation for the period 1985:1 to 2005:1. The series display clear comovement over the sample period (the correlations range between 0.86 and 0.89).

After this rather detailed review of the data, we now turn to the question whether money growth is a useful predictor of inflation in Switzerland.

4 Preliminary evidence

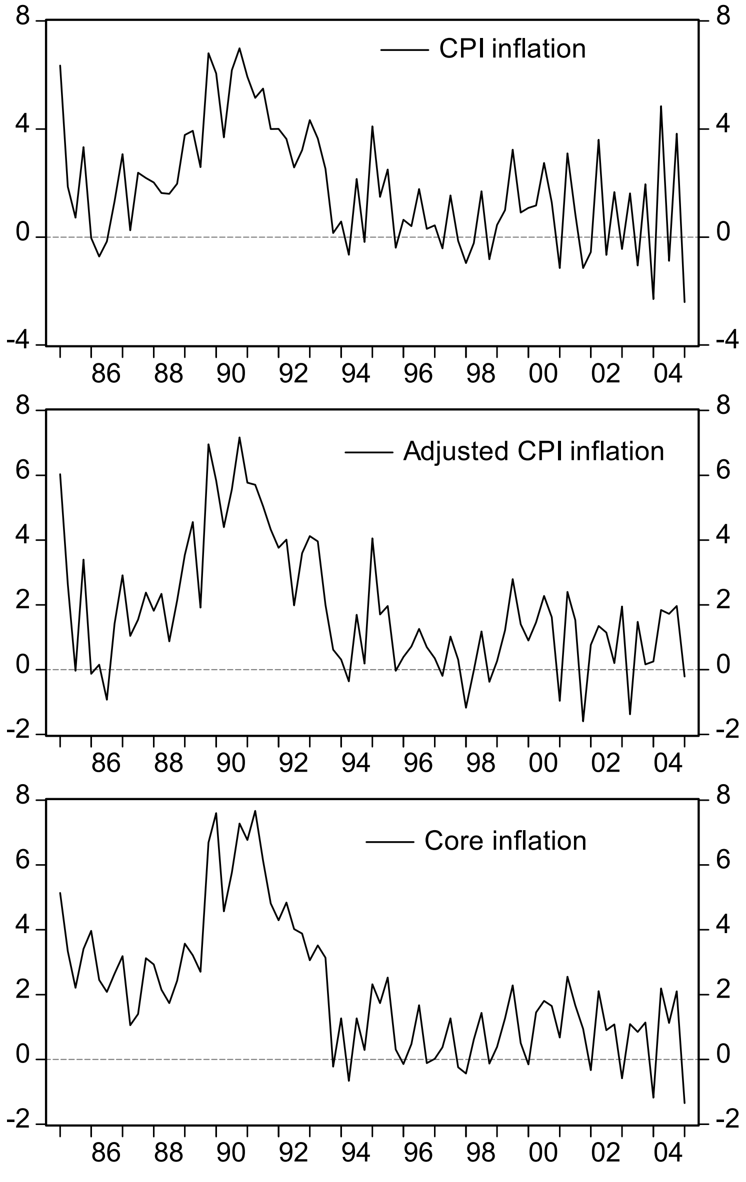
As a first step of the analysis, this section provides preliminary evidence on the link between money growth and inflation in Switzerland. To gain a sense at which horizons money growth might be a useful predictor of future inflation, we regress

$$\pi_{t+j} - \pi_t = F + G\pi_t + H\widetilde{\mu}_t + Ig_t + W_t \tag{6}$$

using GMM, allowing for MA errors of degree $j-1$. Figure 7 shows the coefficients on $\widetilde{\mu}_t$ and the output gap for different forecast horizons together with their 95% confidence bands. In the interest of brevity, we present only the graph we obtain using adjusted CPI inflation and M3 growth. Equation (6) forecasts inflation virtually as well if we consider actual or core inflation. Using M2 instead of M3 growth, however, leads to insignificant coefficient estimates, which suggests that M2 growth might not be a good predictor of future inflation.

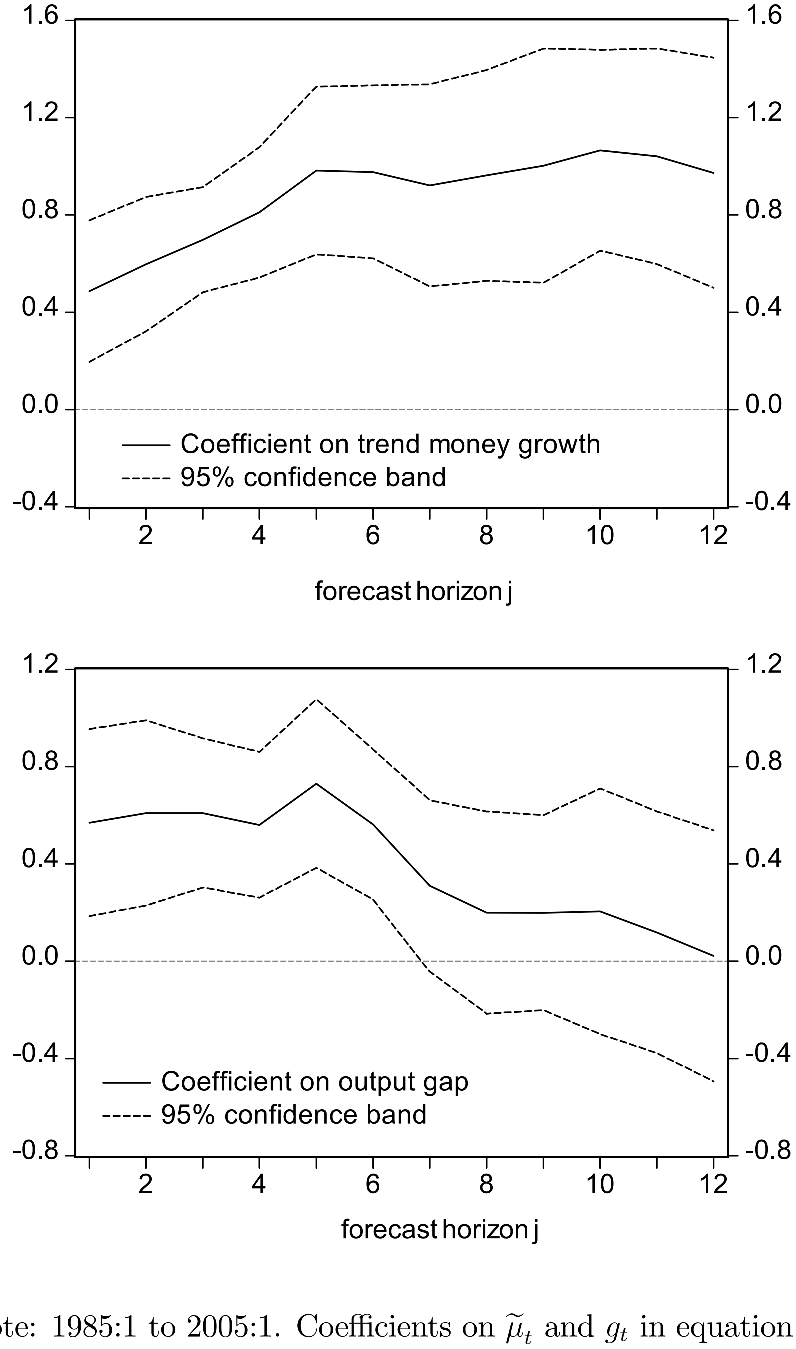
The graph shows that for short forecast horizons, both trend money growth and the output gap help forecast changes in future inflation. Over longer horizons, however, the coefficient on g_t becomes insignificant, while that on $\widetilde{\mu}_t$ increases and reaches a maximum around $j = 10$ quarters. This latter finding is compatible with the study by Jordan, Peytrignet and Rich [17], which shows that M3 growth contains information about infla-

Figure 6: Inflation data



Note: 1985:1 to 2005:1. Annualised quarterly CPI, adjusted CPI and core inflation.

Figure 7: Forecasts coefficients for future inflation



Note: 1985:1 to 2005:1. Coefficients on $\widetilde{\mu}_t$ and g_t in equation (6).

We use adjusted CPI inflation and M3 growth.

tion several years ahead. For $j = 4$ and larger, we do not reject that a $\widetilde{\mu}_t$ of one percentage point leads to an increase of inflation over the next j quarters by the same amount.

Thus, as in the euro area there seems to be a significant link between trend money growth and future inflation in Switzerland. We next proceed to formalising this link by means of the two-pillar Phillips curve.

5 The model

5.1 Traditional Phillips curves

The Phillips curve is an empirical model of inflation that is best interpreted as a reduced form. In its most common form, it states that inflation, π_t, depends on expected future inflation, $E_t\pi_{t+1}$, past inflation and the lagged output gap, g_{t-1}, so that

$$\pi_t = \alpha' + \beta E_t\pi_{t+1} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t, \tag{7}$$

where $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$. Thus, inflation is assumed to be both forward and backward-looking, and often $\beta + \gamma = 1$ is imposed. This assumption implies that if both past and expected inflation rise by one percentage point, inflation today also increases by that amount. While typically $E_t\pi_{t+1}$ is proxied by actual π_{t+1} in estimation, in the context of forecasting the question arises whether other measures of expected inflation can be found that rely on data observable in real time.

Gerlach [13] hypothesises that $E_t\pi_{t+1}$ depends on past money growth, μ_{t-1}. As a first step, we assume that $E_t\pi_{t+1} = \kappa + \mu_{t-1}$ and estimate

$$\pi_t = \alpha + \beta\mu_{t-1} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t, \tag{8}$$

where $\alpha = \alpha' + \beta\kappa$. Table 2 presents the estimation output for equation (8) using M2 growth (Panel A) and M3 growth (Panel B) as well as the three different measures of inflation.[12]

[12] Gerlach [13] also presents estimates based on adjusted money growth, defined as $\mu_t - y_t$, where y_t is the growth rate of real GDP. Using this measure instead of μ_t in our analysis yields similar parameter estimates and leads to the same conclusions. In particular, M2 fares worse than M3 in forecasting inflation in this specification as well.

Table 2: Estimation output for

$$\pi_t = \alpha + \beta\mu_{t-1} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t$$

Panel A: Using M2 growth

Inflation measure	*CPI*	*adjusted CPI*	*core*
α	1.261***	0.814***	0.565**
	(0.337)	(0.274)	(0.245)
β	0.006	0.004	0.021
	(0.031)	(0.024)	(0.020)
γ	0.246**	0.508***	0.655***
	(0.113)	(0.097)	(0.082)
δ	0.595**	0.385*	0.505***
	(0.267)	(0.210)	(0.187)
loglik	-164.850	-144.850	-132.586
p-value ($\beta + \gamma = 1$)	0.000	0.000	0.000

Panel B: Using M3 growth

Inflation measure	*CPI*	*adjusted CPI*	*core*
α	1.092***	0.723**	0.381
	(0.401)	(0.321)	(0.273)
β	0.046	0.026	0.073*
	(0.062)	(0.048)	(0.041)
γ	0.250**	0.509***	0.646***
	(0.112)	(0.097)	(0.081)
δ	0.632**	0.403**	0.519***
	(0.239)	(0.190)	(0.167)
loglik	-164.580	-144.712	-131.509
p-value ($\beta + \gamma = 1$)	0.000	0.000	0.002

Note: Estimates of equation (8), 1985:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level. p-value ($\beta + \gamma = 1$) shows the p-value of a Wald test with the null hypothesis that $\beta + \gamma = 1$.

While most of the regressions in Table 2 yield a significant α, γ and δ, the coefficient on money growth typically is insignificant (in the regression that uses M3 growth and core inflation β is significant at the ten percent level), and β and γ do not seem to sum to unity. While the finding that money growth does not appear to matter for inflation is at odds with the notion that inflation is a monetary phenomenon, it is common in low-inflation economies. We next show how a slightly more general model yields a significant parameter on money growth.

5.2 The two-pillar Phillips curve

Gerlach [13] interprets the ECB as believing that it is not money growth per se, but the filtered measure $\widetilde{\mu}_t$, that affects inflation. He thus assumes that $E_t\pi_{t+1} = \kappa + \widetilde{\mu}_{t-1}$ and estimates

$$\pi_t = \alpha + \beta\widetilde{\mu}_{t-1} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t \tag{9}$$

Following this assumption, we obtain the output reported in Table 3. As Gerlach, we compute $\widetilde{\mu}_t$ assuming that $\lambda = 0.075$.

The estimation output again differs between Panel A, which uses M2 growth, and Panel B, which instead uses M3 growth. We reject $\beta + \gamma = 1$ in Panel A but not in Panel B. Also, while β fails to be significant with the right sign in the first panel, it is highly significant and positive in the second, suggesting that the information content of M3 for future prices is in this model higher than that of M2. One plausible explanation for this finding is that a large part of the movements in M2 is due to substitutions between different forms of money, whereas changes in M3, which takes into account all forms of money, are more directly linked to expected movements in the level of prices. Another explanation for our failure to detect a significant impact of trend M2 growth on future inflation is that the assumption that $\lambda = 0.075$ is far off the true value of the smoothing parameter. We therefore next proceed to estimating this coefficient.

To do so, we substitute out $\widetilde{\mu}_t$ by combining equations (1) and (9). This yields

$$\pi_t = \alpha + \beta\lambda\mu_{t-1} + \beta(1-\lambda)\widetilde{\mu}_{t-2} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t. \tag{10}$$

Table 3: Estimation output for

$$\pi_t = \alpha + \beta\widetilde{\mu}_{t-1} + \gamma\pi_{t-1} + \delta g_{t-1} + \varepsilon_t$$

Panel A: Using M2 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	2.356***	1.425**	1.245**
	(0.658)	(0.572)	(0.537)
β	-0.224*	-0.121	-0.112
	(0.127)	(0.113)	(0.097)
γ	0.185*	0.467***	0.604***
	(0.107)	(0.117)	(0.092)
δ	0.326	0.242	0.305
	(0.303)	(0.223)	(0.214)
loglik	-163.165	-144.070	-132.314
p-value ($\beta + \gamma = 1$)	0.000	0.000	0.001

Panel B: Using M3 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	-1.221	-1.034**	-0.893*
	(0.749)	(0.488)	(0.496)
β	0.675***	0.504***	0.457***
	(0.185)	(0.120)	(0.123)
γ	0.058	0.362***	0.476***
	(0.094)	(0.093)	(0.084)
δ	0.804***	0.539***	0.627***
	(0.222)	(0.159)	(0.162)
loglik	-157.025	-138.337	-125.928
p-value ($\beta + \gamma = 1$)	0.138	0.251	0.550

Note: Estimates of equation (9), 1985:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level. p-value ($\beta + \gamma = 1$) shows the p-value of a Wald test with the null hypothesis that $\beta + \gamma = 1$.

Lagging equation (9) once and solving for $\widetilde{\mu}_{t-2}$ gives

$$\widetilde{\mu}_{t-2} = (\pi_{t-1} - \alpha - \gamma\pi_{t-2} - \delta g_{t-2} - \varepsilon_{t-1})/\beta.$$

Substituting this into equation (10) and rearranging, we obtain

$$\pi_t = \lambda\alpha + \beta\lambda\mu_{t-1} + (1-\lambda+\gamma)\pi_{t-1} + \delta g_{t-1} - (1-\lambda)\gamma\pi_{t-2} - (1-\lambda)\delta g_{t-2} + \eta_t \quad (11)$$

with $\eta_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$. Table 4 shows the estimates of equation (11).

We again find that the coefficient on money growth is insignificant when we use M2 growth to measure μ_t. Moreover, β also fails to be significant if we use M3 growth and actual or adjusted CPI inflation. Only in the equation that combines M3 growth with core inflation do we find a significant role of money growth for future inflation. It is also only in this equation that we estimate a significant smoothing parameter. Its value of 0.04 implies that a unit shock to money growth by one unit moves trend money growth by half a unit in 19 quarters.

Interestingly, we now do not reject that $\beta+\gamma=1$ in any regression. In order to obtain more precise estimates of the coefficients in the model, we introduce as a last step this restriction, fit

$$\begin{aligned}\pi_t = {} & \lambda\alpha + \beta\lambda\mu_{t-1} + [1-\lambda+(1-\beta)]\pi_{t-1} + \delta g_{t-1} \\ & -(1-\lambda)(1-\beta)\pi_{t-2} - (1-\lambda)\delta g_{t-2} + \eta_t\end{aligned} \quad (12)$$

and present the estimation output in Table 5.

We reach several conclusions. First, the data seem indeed compatible with the assumption that $\beta+\gamma=1$ (formal likelihood ratio tests do not reject the hypothesis that this restriction is valid). Second, the coefficient β on trend money growth is in all estimations larger than the coefficient on lagged inflation, indicating that expectations are an important determinant of inflation in Switzerland. Third, the smoothing parameter is highly significant in the M3 models but insignificant in the M2 models. Since we do not reject that $\lambda=0$, the data are compatible with the notion that trend money growth as extracted from M2 growth is a constant. This suggests that movements in M2 growth are not dominated by factors that are related to future inflation. Instead, it seems plausible that interest-rate induced substitution effects drive a large part of the changes in M2. Fourth, the coefficient on the output gap is significant in all estimations. Economic

Table 4: Estimation output for

$$\pi_t = \lambda\alpha + \beta\lambda\mu_{t-1} + (1-\lambda+\gamma)\pi_{t-1} + \delta g_{t-1} - (1-\lambda)\gamma\pi_{t-2} - (1-\lambda)\delta g_{t-2} + \eta_t$$

with $\eta_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$

Panel A: Using M2 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	0.055	0.038	0.024
	(0.057)	(0.042)	(0.038)
β	-1.226	-0.743	-0.920
	(1.870)	(1.383)	(1.404)
γ	0.043	0.337***	0.390***
	(0.112)	(0.111)	(0.111)
δ	0.430	0.311	0.443**
	(0.284)	(0.222)	(0.201)
λ	0.012	0.013	0.010
	(0.017)	(0.019)	(0.013)
loglik	-163.199	-147.315	-129.529
p-value ($\beta+\gamma=1$)	0.246	0.319	0.291

Panel B: Using M3 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	-0.145***	-0.103**	-0.082***
	(0.051)	(0.042)	(0.032)
β	1.660	1.022	0.776**
	(1.017)	(0.762)	(0.389)
γ	-0.013	0.277***	0.421***
	(0.102)	(0.100)	(0.095)
δ	0.857***	0.621***	0.655***
	(0.242)	(0.185)	(0.164)
λ	0.027	0.034	0.034*
	(0.019)	(0.028)	(0.020)
loglik	-159.285	-143.268	-126.793
p-value ($\beta+\gamma=1$)	0.513	0.682	0.579

Note: Estimates of equation (11), 1985:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level. p-value ($\beta+\gamma=1$) shows the p-value of a Wald test with the null hypothesis that $\beta+\gamma=1$.

Table 5: Estimation output for

$$\pi_t = \lambda\alpha + \beta\lambda\mu_{t-1} + [1-\lambda+(1-\beta)]\pi_{t-1} + \delta g_{t-1}$$
$$-(1-\lambda)(1-\beta)\pi_{t-2} - (1-\lambda)\delta g_{t-2} + \eta_t$$
$$\text{with } \eta_t = \varepsilon_t - (1-\lambda)\varepsilon_{t-1}$$

Panel A: Using M2 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	-0.010	-0.012	-0.019
	(0.023)	(0.018)	(0.012)
β	0.966***	0.659***	0.576***
	(0.117)	(0.112)	(0.110)
δ	0.549**	0.402**	0.519***
	(0.253)	(0.203)	(0.181)
λ	-0.010	-0.006	-0.006
	(0.008)	(0.010)	(0.008)
loglik	-163.662	-147.823	-130.308
p-value LR test	0.336	0.313	0.212
p-value break	0.001	0.047	0.011

Panel B: Using M3 growth			
Inflation measure	*CPI*	*adjusted CPI*	*core*
α	-0.105***	-0.080***	-0.065***
	(0.032)	(0.024)	(0.020)
β	0.998***	0.711***	0.572***
	(0.099)	(0.099)	(0.094)
δ	0.854***	0.617***	0.653***
	(0.240)	(0.183)	(0.164)
λ	0.042***	0.046***	0.044**
	(0.016)	(0.017)	(0.019)
loglik	-159.826	-143.525	-127.042
p-value LR test	0.298	0.473	0.480
p-value break	0.003	0.223	0.031

Note: Estimates of equation (12), 1985:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level. p-value LR test denotes the probability in a likelihood ratio test for the hypothesis that the restrictions imposed by equation (12) on equation (11) are valid. p-value break denotes the probability that the fit of two models estimated for the subsamples 1985:1 to 1994:4 and 1995:1 to 2005:1 is equally good as that of the model estimated on the entire sample period.

activity thus seems to help forecast future inflation. Fifth, whereas the residuals in the equations using actual CPI and core inflation display signs of serial correlation, this is not the case if we use adjusted CPI inflation. This result is reported in Table 6, which also indicates that non-normality and autoregressive conditional heteroskedasticity do not seem present in the residuals. Sixth, the specification involving M3 growth and adjusted CPI inflation is the only model that appears stable throughout the sample. If we split the estimation period in the middle, a likelihood ratio test comparing the sum of the likelihoods of the two subsamples with that obtained for the entire sample yields for this specification a p-value of 0.22. For all other setups, the test values reported in Table 5 indicate that fitting the two subsamples separately is preferable to assuming on stable model for the whole estimation period.

Table 6: Residual tests

	Normality (Jarque-Bera)	Fourth-order serial correlation	ARCH LM(1)
	Panel A: Using M2 growth		
CPI	0.710	0.003	0.410
adjusted CPI	0.701	0.225	0.940
core	0.713	0.000	0.908
	Panel B: Using M3 growth		
	Normality (Jarque-Bera)	Fourth-order serial correlation	ARCH LM(1)
CPI	0.468	0.041	0.361
adjusted CPI	0.782	0.552	0.681
core	0.518	0.001	0.831

Note: p-values of residuals tests for different specifications of equation (12).

We thus have established that the two-pillar Phillips curve proposed by Gerlach [13] for the euro area also fits Swiss inflation data. This can be interpreted as evidence that this model has broad validity. From a policy point of view, the results suggest that monitoring Swiss money growth is useful for forecasting inflation. In order to assess whether this result is sensitive to the exact model chosen, we next turn to an alternative

Phillips curve specification that also includes a filtered measure of money.

6 Sensitivity analysis

Neumann [24] proposes a specification of the Phillips curve that takes into account the ECB's monetary pillar but that differs in three ways from Gerlach's model. The first difference concerns the measure of money. Neumann points out that the measure of trend money growth, $\widetilde{\mu}_t$, which is obtained using a one-sided filter on money growth, lies by construction above actual money growth if the latter is declining. He therefore proposes using the Hodrick-Prescott filter, which is two-sided, to derive a measure of "core" money growth, $\overline{\mu}_t$, that is not subject to this shortcoming.[13, 14]

Figure 8 shows in the upper plot adjusted CPI inflation and trend money growth obtained from equation (12) and in the lower plot inflation and core money growth.[15] Since trend and core money growth have the greatest forecasting ability for inflation several quarters ahead (8 quarters for trend, 15 quarters for core money growth), we lead these two series in the graph. The plots suggest that both trend and core money growth predicted the disinflation after 1990 but show a less clear link with inflation towards the end of the sample, when π_t was close to zero. We also see that core money growth is much smoother than trend money growth.

The second difference between Neumann's and Gerlach's models concerns the specification of the Phillips curve. Neumann's Phillips curve is given by

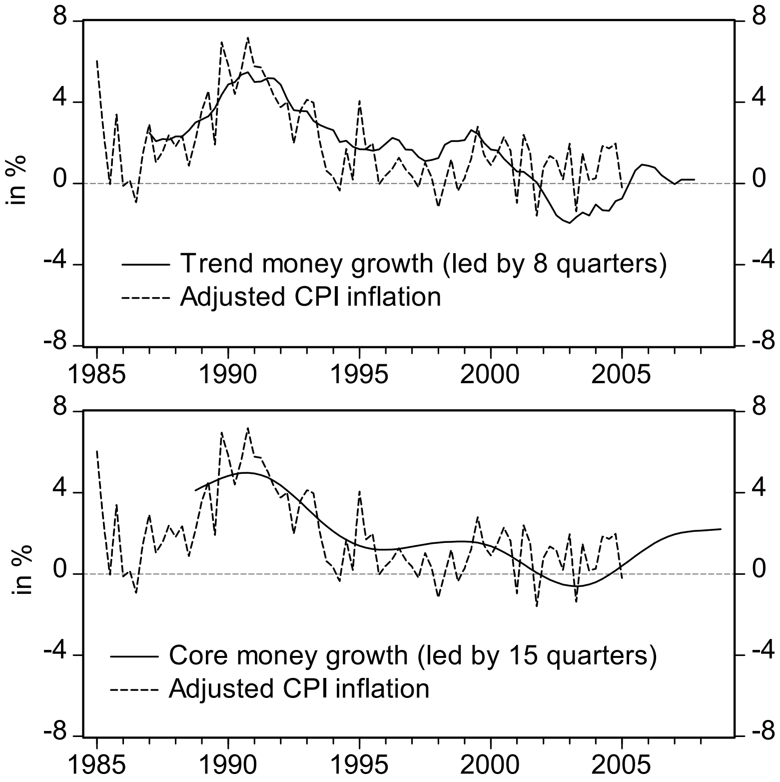
$$\pi_t = E_{t-1}\pi_t + \varphi g_{t-1} + \omega_t. \tag{13}$$

[13]From a forecasting point of view two-sided filters are less attractive since they attach a large weight to the last observation in sample. A second reason for preferring a one-sided filter is that future money growth may be correlated with future inflation, thereby exaggerating the correlation between current core money growth and future inflation. A third weakness of the Hodrick-Prescott filter is that the degree of smoothing is imposed rather than estimated.

[14]Neumann and Greiber [25] also present estimations using alternative filters and find that the model is robust to such changes.

[15]We obtain $\widetilde{\mu}_t$ using the parameter estimates fitted for the specification of equation (12) that is based on adjusted CPI inflation and M3 growth. Following Neumann, we calculate $\overline{\mu}_t$ using the Hodrick-Prescott filter with a smoothing parameter of 1600.

Figure 8: Adjusted CPI inflation, trend money growth and core money growth



Note: 1985:1 to 2008:4. Trend money growth is calculated from equation (12) using adjusted CPI inflation and M3 growth, core money is obtained with a Hodrick-Prescott filter (smoothing parameter of 1600). Trend and core money growth have been normalised to have the same mean and standard deviation as adjusted CPI inflation.

Thus, the timing of expectations differs from the two-pillar model and neither a constant nor lagged inflation are included. The third difference arises from the modelling of inflation expectations. Gerlach sets $E_t\pi_{t+1} = \kappa + \widetilde{\mu}_{t-1}$, while Neumann assumes that

$$E_t\pi_{t+1} = \rho\pi_t + (1-\rho)\overline{\pi}_t, \tag{14}$$

where $\overline{\pi}_t$ denotes core inflation and is given by

$$\overline{\pi}_t = \overline{\mu}_t - \phi\overline{y}_t. \tag{15}$$

The variable $\overline{y}_t$ denotes potential output growth. It should be noted that equation (15) represents the first difference of the long-run components of money demand, so that the parameter ϕ reflects the income elasticity. Combining equations (13), (14) and (15) yields

$$\pi_t = (1-\rho)(\overline{\mu}_{t-1} - \phi\overline{y}_{t-1}) + \rho\pi_{t-1} + \varphi g_{t-1} + \omega_t. \tag{16}$$

Thus, inflation is expected to increase if core money growth lies above the potential growth rate of GDP multiplied by the income elasticity and if past inflation or economic activity were high.

To study whether money also under this model contains information regarding future Swiss inflation, we estimate equation (16) using M2 and M3 growth and our three measures of inflation. Table 7 presents the results. We again find that the estimations based on M3 rather than M2 growth yield more significant parameters. The point estimates of income elasticity are close to unity but insignificant for the M2 models, whereas using M3 growth yields significant estimates of ϕ between 1.2 and 1.4. These values are close to those commonly reported for Switzerland (see e.g. Peytrignet and Stahel [27]). It has been argued that an elasticity greater than unity can arise for broad monetary aggregates since certain interest-rate bearing forms of money grow faster than GDP and are held for portfolio considerations (see e.g. Knell and Stix [19]).

Table 8 indicates that there is evidence of serial correlation in the residuals for all specifications of equation (16). Evidence of non-stability of the model is found only if we use actual CPI inflation, as can be seen from the p-values in Table 7. Thus, stability is less of a concern for the core-money model than for the two-pillar Phillips curve, while

Table 7: Estimation output for

$$\pi_t = (1-\rho)(\overline{\mu}_{t-1} - \phi\overline{y}_{t-1}) + \rho\pi_{t-1} + \varphi g_{t-1} + \omega_t$$

Panel A: Using M2 growth

Inflation measure	*CPI*	*adjusted CPI*	*core*
ρ	0.778***	0.890***	0.926***
	(0.080)	(0.061)	(0.051)
ϕ	1.112	1.123	0.933
	(0.704)	(1.043)	(1.299)
φ	0.359	0.164	0.227
	(0.287)	(0.213)	(0.179)
loglik	-179.713	-154.965	-140.285
p-value break	0.002	0.245	0.579

Panel B: Using M3 growth

Inflation measure	*CPI*	*adjusted CPI*	*core*
ρ	0.319***	0.576***	0.644***
	(0.115)	(0.098)	(0.090)
ϕ	1.433***	1.430***	1.211***
	(0.200)	(0.248)	(0.248)
φ	0.723***	0.442**	0.518***
	(0.250)	(0.199)	(0.176)
loglik	-168.571	-147.904	-133.929
p-value break	0.016	0.672	0.752

Note: Estimates of equation (16), 1985:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level. p-value break denotes the probability that the fit of two models estimated for the subsamples 1985:1 to 1994:4 and 1995:1 to 2005:1 is equally good as that of the model estimated on the entire sample period.

the residuals show fewer problems in the latter setup. In comparison with the two-pillar Phillips curve, the core-money model yields slightly lower log likelihood values. Formal J-tests, however, do not indicate that either model is superior.

Table 8: Residual tests

	Normality (Jarque-Bera)	Fourth-order serial correlation	ARCH LM(1)
Panel A: Using M2 growth			
CPI	0.993	0.000	0.000
adjusted CPI	0.508	0.005	0.108
core	0.929	0.000	0.569
Panel B: Using M3 growth			
CPI	0.346	0.000	0.124
adjusted CPI	0.888	0.039	0.573
core	0.683	0.000	0.659

Note: p-values of residuals tests for different specifications of equation (16).

The main conclusion to be drawn from this sensitivity analysis is that inflation models that include a filtered version of M3 growth seem to be useful forecasting tools not only in the euro area but also in Switzerland. The link between M2 growth and future inflation, which is considered by neither Gerlach nor Neumann, seems weak in both models, which may be due to the fact that movements in M2 are to a large extent caused by interest rate changes and thus do not reveal new information on future inflation.

7 Conclusions

This paper shows that a two-pillar Phillips curve, which originally was proposed by Gerlach [13] as an interpretation of the ECB's view of inflation dynamics in the euro area, also fits Swiss data. We consider actual CPI inflation, adjusted CPI inflation, which attempts to correct for changes introduced by an index revision in 2000, and core inflation.

Estimations using adjusted CPI inflation yield a two-pillar Phillips curve the residuals of which suggest it is well specified, while considering the other two inflation series results in correlated residuals.

Since it is not clear which monetary aggregate should be used, we consider both M2 and M3 in the estimation and find that the specifications of the two-pillar Phillips curve using M3 growth yield more plausible and precise parameter estimates. This finding may be due to the fact that we do not account for the interest rate sensitivity of M2. The regressions suggest that inflation seems backward and forward-looking and to be driven by the output gap and a low-frequency component of money growth.

As a robustness check, we also estimate the Phillips curve model proposed by Neumann [24]. He shows for the euro area that a filtered measure of money growth based on the Hodrick-Prescott filter seems to impact through a money demand effect on future inflation. When using Swiss data we reach the same finding and also here observe a better fit in the case of M3 than of M2 growth. Overall, this paper indicates that M3 growth is an important determinant of inflation not only in the euro area but also in Switzerland.

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