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 [16] 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 [28].

Keywords: inflation, money, Phillips curve, Switzerland
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1 Introduction

While inflation is commonly seen 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).

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.[2] The first pillar assigns money "a prominent role" in guiding the Governing Council's policy decisions. In particular, M3 growth of 4.5% per year is seen compatible with price stability. Deviations from this reference value are taken as indication of inflationary pressures but do not trigger automatic policy responses. The second pillar combines "a wide range of economic and financial variables" to assess future price developments. 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. The first pillar provides insights with respect to inflation in the medium to long run and can be used to "cross-check" the implications of the real-side analysis (ECB [11] and Issing [17]).

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.[3] Since 2000 the SNB has aimed at maintaining 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 [21] describe the first set as variables "useful for forecasting short-run price developments", such as the output gap, labour

[1] See e.g. de Grauwe and Polan [7]. However, Nelson [27] challenges their analysis.

[2] The ECB's first Monthly Bulletin [10] reviews its monetary policy strategy in detail. See also ECB [8] and [9].

[3] Peytrignet [31] and Rich [33] provide detailed discussions of Swiss monetary policy before 2000.

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 [34]). In contrast to the ECB, the SNB does not analyse monetary and real factors in two separate pillars. Instead, the information from these two sets of indicators is combined to yield the inflation forecast on which policy decisions then are based. Thus, there is no formal cross-checking as at the ECB, nor has a reference value for the growth rate of M3 been specified.[4]

There are three broad stances in the literature on the role of money growth in the inflation process. The first is that money growth does not forecast inflation at all. For instance, Begg, Canova, De Grauwe, Fatas and Lane [3] demonstrate that money does not seem to impact on prices in the euro area and, based on this evidence, criticise the ECB's two-pillar strategy. The second stance is that long-term trends in money growth impact on the average rate of inflation. Gerlach [16] and Neumann [28] propose for the euro area Phillips curve models in which inflation depends on the low-frequency component of changes in M3, which represents the first pillar, and on the output gap, which captures the second pillar. The third stance is that money growth explains movements in inflation also in the short term. Nelson [27] argues that changes in money growth affect inflation by impacting on aggregate demand. Since the output gap measures aggregate demand pressure and since shifts in velocity may obscure the short-run link between money growth and inflation, it is possible that the output gap, but not money growth, is significant in the Phillips curve.[5] The results presented in this paper are compatible with the second and third hypothesis regarding the role of money in the inflation process, but not with the first.

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[4]Jordan, Peytrignet and Rich [21] argue that the SNB's difficulties in reaching its money growth targets before 2000 rendered a numerical reference value unattractive.

[5]The referee has pointed out that the output gap should matter only if prices are sticky. Under flexible prices, the output gap is zero and the link between money growth and inflation is more direct. Nelson [27] argues that the gap is subject to measurement problems and thus may not be superior to money growth in forecasting inflation. We return to this point in Sections 3 and 4 below. Coenen, Levin and Wieland [5] show that output estimates for the euro area can be improved by making use of monetary data.

We start out by demonstrating that actual money growth is insignificant in a simple Phillips curve for Switzerland. The SNB's reliance on monetary, as well as real, data could thus be criticised. We then, however, go on to show that filtered money growth helps forecast inflation in Switzerland and estimate the two-pillar Phillips curve, which fits the data well. Our analysis supports the notion that money predicts prices in Switzerland, which implies that Gerlach's [16] 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 is in line with findings for the euro area and may be due to the higher interest rate sensitivity of M2 and the fact that nominal interest rates followed a downward trend over the sample.[6] 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 measured inflation. Our proposed approach is a simple statistical 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 [28] 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

[6] I thank the referee for pointing this out.

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 [28]. 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 hybrid models that combine forward and backward-looking elements (e.g. Fuhrer and Moore [14]).

Several authors have estimated Phillips curves for Switzerland. Zanetti [37], 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 [26] 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 [36] 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 [25] 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 models used in the inflation forecasting process of the SNB (see Jordan and Peytrignet [20] for an overview of the different models in use). In the so-called small macro model, the Phillips curve includes the output gap, past and future inflation and the change in the exchange rate. 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 [35]).

A number of authors have studied the impact of money on inflation in Switzerland without using the concept of the Phillips curve. Baltensperger, Jordan and Savioz [2] consider inflation equations that comprise money growth and the difference between actual 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 [21] 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 [32] 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. Jordan and Savioz [22] 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 [24], 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.

The paper most closely related to ours is Assenmacher-Wesche and Gerlach [1]. Using spectral techniques they estimate a two-pillar Phillips curve for Switzerland and establish that low-frequency money growth impacts on long-run inflation, whereas short-term movements in inflation seem to be explained by the output gap. The present paper follows a simpler approach, proposed by Gerlach [16], to show that while money growth per se tends to be insignificant in the Swiss Phillips curve, a more slowly evolving filtered version thereof is a useful indicator of future 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. Nevertheless, the output gap is an uncertain variable for two reasons. First, the underlying GDP data often are subject to revisions, rendering especially the most recent observations on the output gap unreliable. Second, potential output $\overline{Y}_t$ is itself an unobserved variable that needs to be estimated, and it is not clear how to best model its behaviour. Lacking a perfectly measured output gap, we use the Hodrick-Prescott measure in the estimations below. The conclusions of the paper are the same if we use the production-function output gap instead.

3.2 Money growth

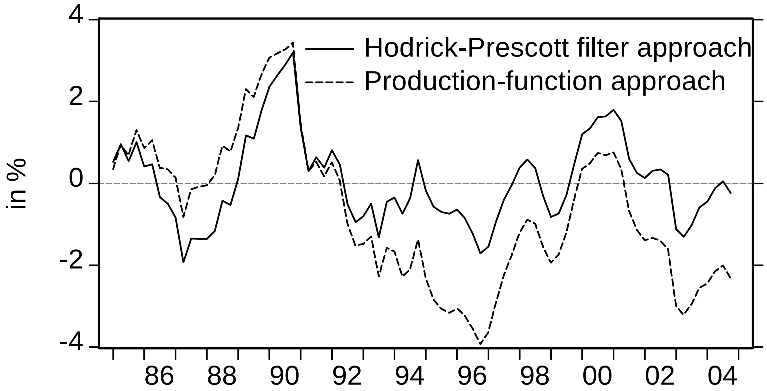
Both Gerlach [16] and Neumann [28] use M3 as their measure of money, presumably because the ECB's reference value is set with respect to the growth rate of that monetary aggregate. It is a priori not clear whether the growth rate μ_t of M2 or M3 is better able to forecast future inflation. Nicoletti-Altimari [30] demonstrates that inflation models using M3 growth perform in the euro area better than models based on M2 growth, which is compatible with the ECB's focus on M3 growth in its first pillar.

Fischer and Peytrignet [13] show for Switzerland that M3 growth was a poor predictor for inflation until the end-1980s, but Rich [33] demonstrates that it became a useful indicator in the 1990s. We therefore consider M2 as well as M3 growth in the analysis.[8]

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

[8] Jordan, Kugler, Lenz and Savioz [19] present Granger causality tests in which M1, M2 and M3 all

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.

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 [16] using a one-sided exponential filter as

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

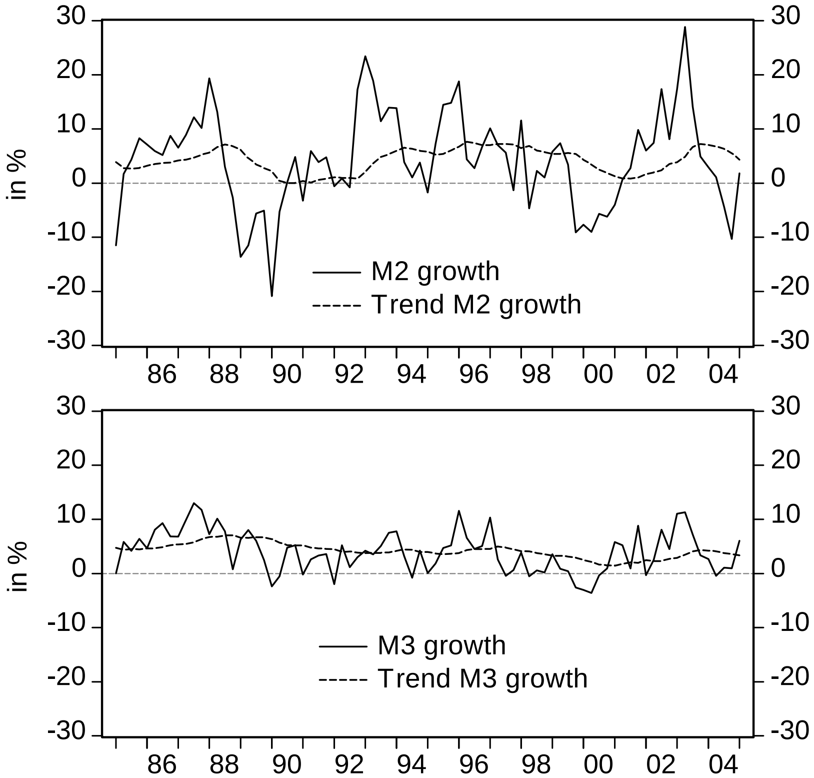
Trend money growth thus is a weighted average of current money growth and past trend growth, where the parameter λ determines the weight on current money growth.[9] As Gerlach, we initially set $\lambda = 0.075$, which implies that a one-unit shock to μ_t triggers a 0.5 unit reaction in $\widetilde{\mu}_t$ 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

cause future inflation in Switzerland. Peytrignet and Stahel [32] argue that M3 is more useful than M2 in forecasting inflation.

[9] Cogley [6] 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 [4] and Jaeger [18].

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).

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

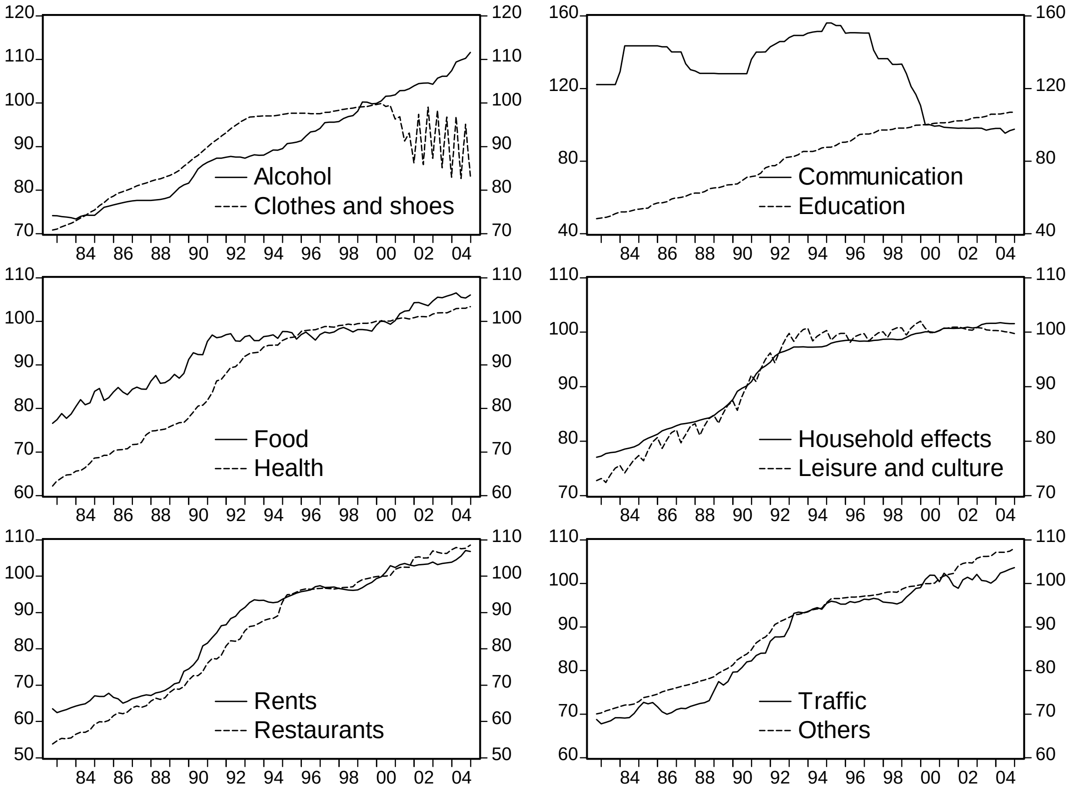
For inflation, π_t, we consider CPI inflation, adjusted CPI inflation and core inflation. Core inflation is a trimmed mean of CPI inflation that excludes the top and bottom 15 percent of price movements. While central banks typically define their understanding of price stability in terms of consumer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

[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.

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

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

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

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.

Table 1: State space estimates for

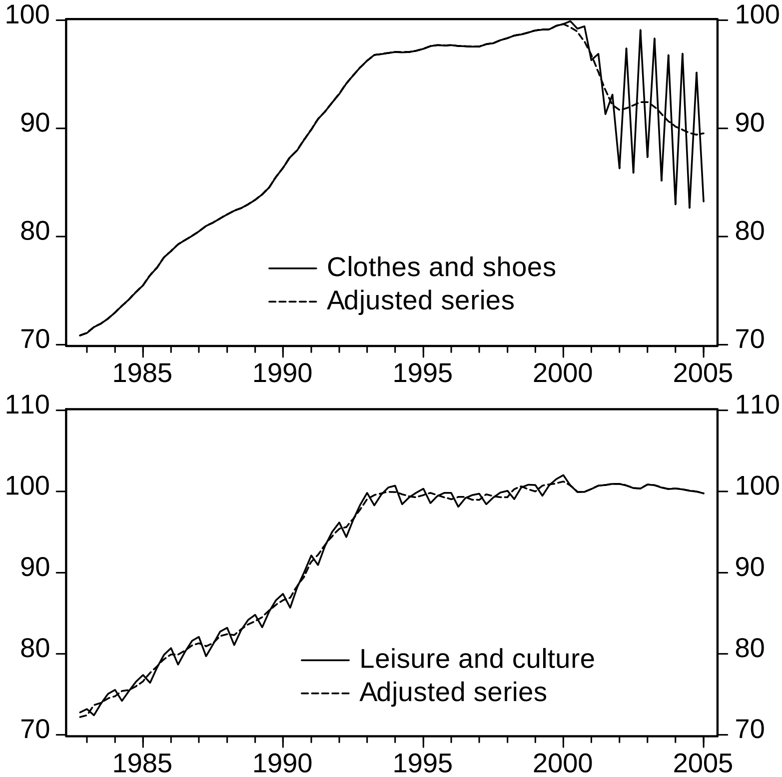
equations (2), (3) and (4) for clothes and shoes

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

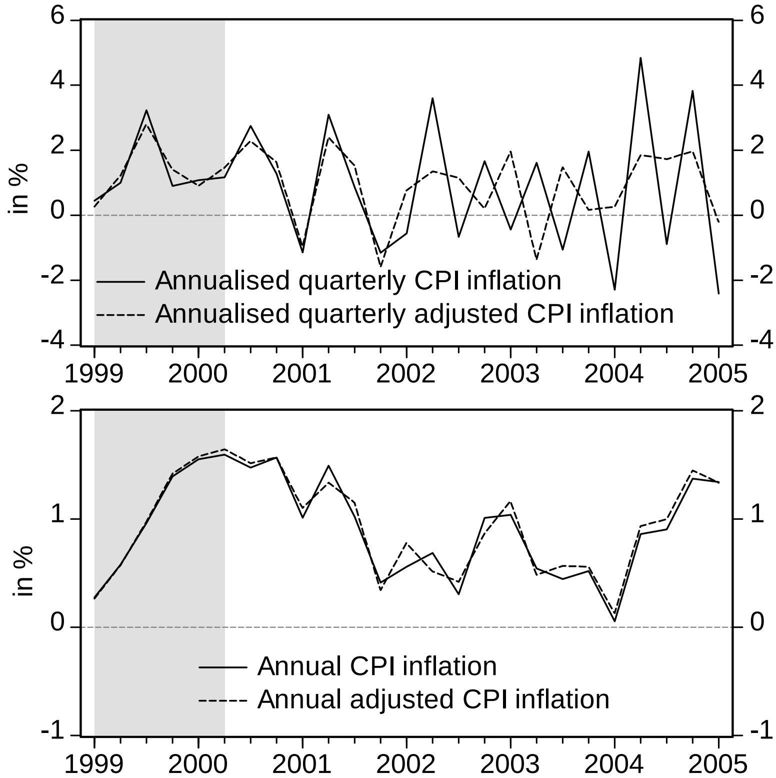
Note: State-space estimates, 1983:1 to 2005:1. Standard errors in parentheses. */**/*** denotes significance at the ten / five / one percent level.

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.

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 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 and thus presumably gives rise to less autocorrelation in the residuals of the Phillips curve, 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

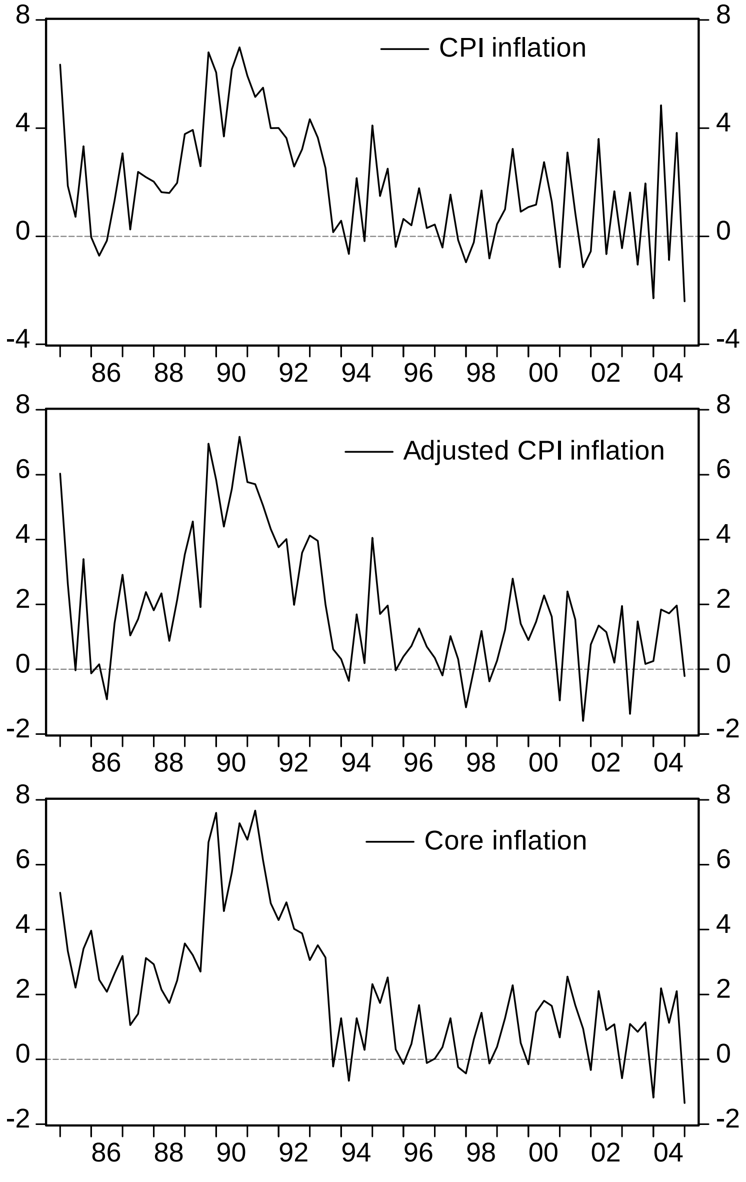
As a first step of the analysis, this section provides preliminary evidence on the link between money growth and inflation in Switzerland. To gain a sense at which horizons money growth might be a useful predictor of future inflation, we regress

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

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

[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.

Figure 6: Inflation data



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

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.[12] 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. These findings are compatible with the study by Jordan, Peytrignet and Rich [21], which shows that M3 growth contains information about inflation several years ahead. Assenmacher-Wesche and Gerlach [1] report that the output gap has the strongest predictive power for inflation two to three years ahead and that money Granger-causes inflation for horizons longer than a year. Interestingly, this latter result contrasts with the significant parameter on $\widetilde{\mu}_t$ already from $j = 1$ onwards in our regression. Moreover, we do not reject that a rise in $\widetilde{\mu}_t$ by one percentage point leads to an increase of inflation over the next j quarters by the same amount for $j = 4$ and larger. Assenmacher-Wesche and Gerlach [1], by contrast, reject such a one-to-one impact in their study.

Overall, the preliminary evidence suggests that there seems to be a significant link between trend money growth and future inflation also in Switzerland. We next proceed to formalising this link by means of the two-pillar Phillips curve.

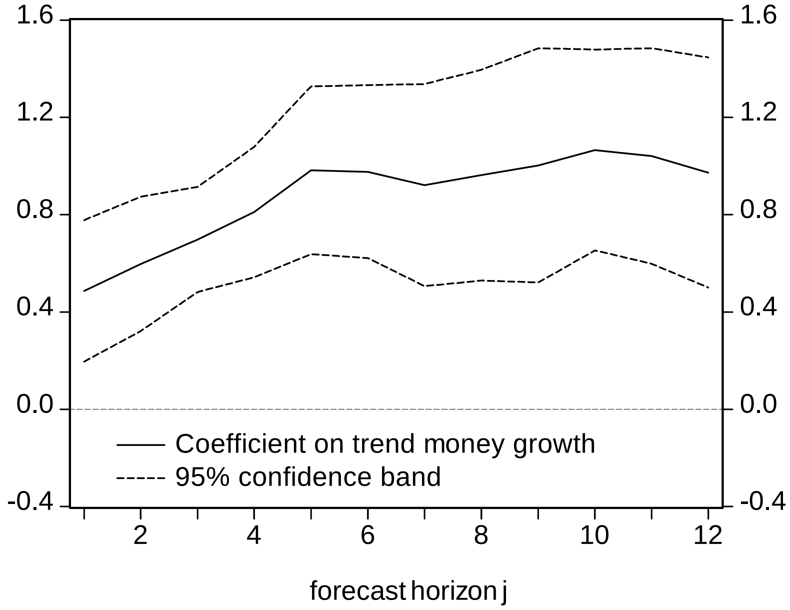
5 The model

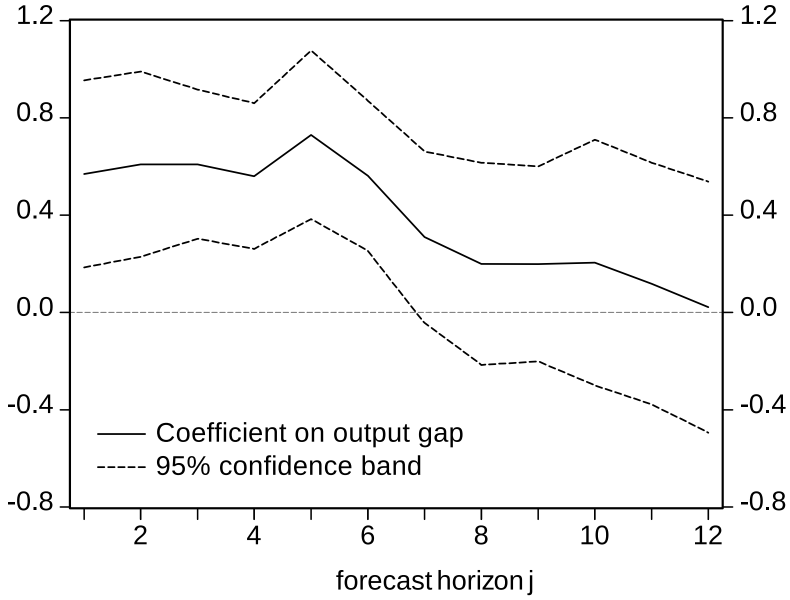
5.1 Traditional Phillips curves

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 past inflation and

[12] The finding that both filtered money growth and the output gap matter for short-term inflation is compatible with the notion that μ_t and g_t are subject to measurement error. I thank the referee for pointing this out.

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.

the lagged output gap, g_{t-1}, so that

$$\pi_t = \alpha + \beta\pi_{t-1} + \gamma g_{t-1} + \varepsilon_t, \tag{7}$$

where $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$. The usual way to test whether money growth, μ_t, forecasts inflation is to include its past value in the Phillips curve.[13] We thus fit

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

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.[14] While most of the regressions in Table 2 yield significant estimates of α, β and γ, the coefficient on money growth typically is insignificant (in the regression that uses M3 growth and core inflation δ is significant at the ten percent level). In the last line of each panel, we test whether the long-run impact of money growth on inflation is unity, as predicted by the quantity theory. The Wald test that $\delta/(1-\beta) = 1$ rejects for all combinations of money growth and inflation measures.

The finding that money growth does not appear to forecast inflation is common in low-inflation economies. We next show that trend, rather than headline, money growth appears to impact on inflation.

5.2 The two-pillar Phillips curve

Gerlach [16] interprets the ECB as believing that it is not money growth per se, but the filtered measure $\widetilde{\mu}_t$, that affects inflation. He therefore estimates

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

[13] Gerlach [16], whose model we follow below, starts out from a hybrid Phillips curve in which current inflation is a function of past and expected future inflation and the lagged output gap. He then hypothesises that inflation expectations depend on past money growth and obtains an equation of the same form as our equation (8).

[14] Gerlach [16] 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

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

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	0.246**	0.508***	0.655***
	(0.113)	(0.097)	(0.082)
γ	0.595**	0.385*	0.505***
	(0.267)	(0.210)	(0.187)
δ	0.006	0.004	0.021
	(0.031)	(0.024)	(0.020)
loglik	-164.850	-144.850	-132.586
p-value for $\delta/(1-\beta) = 1$	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	0.250**	0.509***	0.646***
	(0.112)	(0.097)	(0.081)
γ	0.632**	0.403**	0.519***
	(0.239)	(0.190)	(0.167)
δ	0.046	0.026	0.073*
	(0.062)	(0.048)	(0.041)
loglik	-164.580	-144.712	-131.509
p-value for $\delta/(1-\beta) = 1$	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. The last line in each panel shows the p-value of a Wald test with the null hypothesis that $\delta/(1-\beta) = 1$.

Fitting this equation for Swiss data, we obtain the output reported in Table 3. As Gerlach, we compute $\widetilde{\mu}_t$ in a first step by assuming that $\lambda = 0.075$.

The results in Table 3 differ between Panel A, which uses M2 growth, and Panel B, which instead uses M3 growth. We reject $\delta/(1-\beta) = 1$ in Panel A but not in Panel B. Also, while δ fails to be significant with the right sign in the first panel, it is highly significant and positive in the second, suggesting that trend M3, but not M2, predicts future prices. This may be due to the lower interest rate sensitivity of broader monetary aggregates and to the downward trend of nominal interest rates over the sample. Moreover, the output gap does not appear to matter in the model using M2, either, while it has a highly significant impact on inflation in the model using M3.

It is possible that our failure to detect a significant impact of trend M2 growth on future inflation arises because 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 $\widetilde{\mu}_{t-1}$ by combining equations (1) and (9). This yields

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

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

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

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

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

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, δ 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 weakly significant role of money growth for future inflation. It is also only in this equation that we estimate a significant smoothing parameter.

Interestingly, we do not reject that $\delta/(1-\beta) = 1$ in any regression of Table 4. Thus, the data are compatible with the notion that the long-run impact of money growth on

Table 3: Estimation output for

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

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	0.185*	0.467***	0.604***
	(0.107)	(0.117)	(0.092)
γ	0.326	0.242	0.305
	(0.303)	(0.223)	(0.214)
δ	-0.224*	-0.121	-0.112
	(0.127)	(0.113)	(0.097)
loglik	-163.165	-144.070	-132.314
p-value for $\delta/(1-\beta)=1$	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	0.058	0.362***	0.476***
	(0.094)	(0.093)	(0.084)
γ	0.804***	0.539***	0.627***
	(0.222)	(0.159)	(0.162)
δ	0.675***	0.504***	0.457***
	(0.185)	(0.120)	(0.123)
loglik	-157.025	-138.337	-125.928
p-value for $\delta/(1-\beta)=1$	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. The last line of each panel shows the p-value of a Wald test with the null hypothesis that $\delta/(1-\beta)=1$.

Table 4: Estimation output for

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

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	0.043	0.337***	0.390***
	(0.112)	(0.111)	(0.111)
γ	0.430	0.311	0.443**
	(0.284)	(0.222)	(0.201)
δ	-1.226	-0.743	-0.920
	(1.870)	(1.383)	(1.404)
λ	0.012	0.013	0.010
	(0.017)	(0.019)	(0.013)
loglik	-163.199	-147.315	-129.529
p-value for $\delta/(1-\beta)=1$	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	-0.013	0.277***	0.421***
	(0.102)	(0.100)	(0.095)
γ	0.857***	0.621***	0.655***
	(0.242)	(0.185)	(0.164)
δ	1.660	1.022	0.776**
	(1.017)	(0.762)	(0.389)
λ	0.027	0.034	0.034*
	(0.019)	(0.028)	(0.020)
loglik	-159.285	-143.268	-126.793
p-value for $\delta/(1-\beta)=1$	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. The last line of each panel shows the p-value of a Wald test with the null hypothesis that $\delta/(1-\beta)=1$.

inflation is unity, as theory would predict. We next impose this restriction by replacing β with $1-\delta$ in the estimation. Thus, we fit

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

and present the estimation output in Table 5.

We reach several conclusions. First, the data seem indeed compatible with the assumption that $\delta/(1-\beta) = 1$ (formal likelihood ratio tests do not reject the hypothesis that this restriction is valid). Second, the smoothing parameter is highly significant in the M3 models but insignificant in the M2 models. The data hence suggest that trend money growth as extracted from M2 growth is a constant. This finding is compatible with Nicoletti-Altimari [30], who shows that M3 growth forecasts inflation better than M2 growth in the euro area. Third, the coefficient on the output gap is significant in all estimations. Economic activity thus seems to help forecast future inflation. Fourth, 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 probably due to the fact that actual CPI and core inflation are more volatile after the change in the computation of the CPI in May 2000. We report these findings in Table 6, which also indicates that non-normality and autoregressive conditional heteroskedasticity do not seem present in the residuals. Fifth, 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 (reported as "p-value break" in the table). For all other setups, the test values reported in Table 5 indicate that fitting the two subsamples separately is preferable to assuming a stable model for the whole estimation period.

We thus have established that the two-pillar Phillips curve proposed by Gerlach [16] 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 imply 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

Table 5: Estimation output for

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

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

Panel A: Using M2 growth

Inflation measure	*CPI*	*adjusted CPI*	*core*
α	-0.010	-0.012	-0.019
	(0.023)	(0.018)	(0.012)
γ	0.549**	0.402**	0.519***
	(0.253)	(0.203)	(0.181)
δ	0.966***	0.659***	0.576***
	(0.117)	(0.112)	(0.110)
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)
γ	0.854***	0.617***	0.653***
	(0.240)	(0.183)	(0.164)
δ	0.998***	0.711***	0.572***
	(0.099)	(0.099)	(0.094)
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.

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).

specification that also includes a filtered measure of money.

6 Sensitivity analysis

Neumann [28] proposes a specification of the Phillips curve that takes into account the ECB's monetary pillar but that differs in two important 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.[15, 16]

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.[17] 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

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

Thus, inflation depends on no constant, lagged inflation expectations and the lagged output gap. Neumann assumes that inflation expectations are given by

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

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

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

with $\overline{y}_t$ denoting potential output growth.[18] It should be noted that equation (15) represents the first difference of the long-run components of money demand, so that the

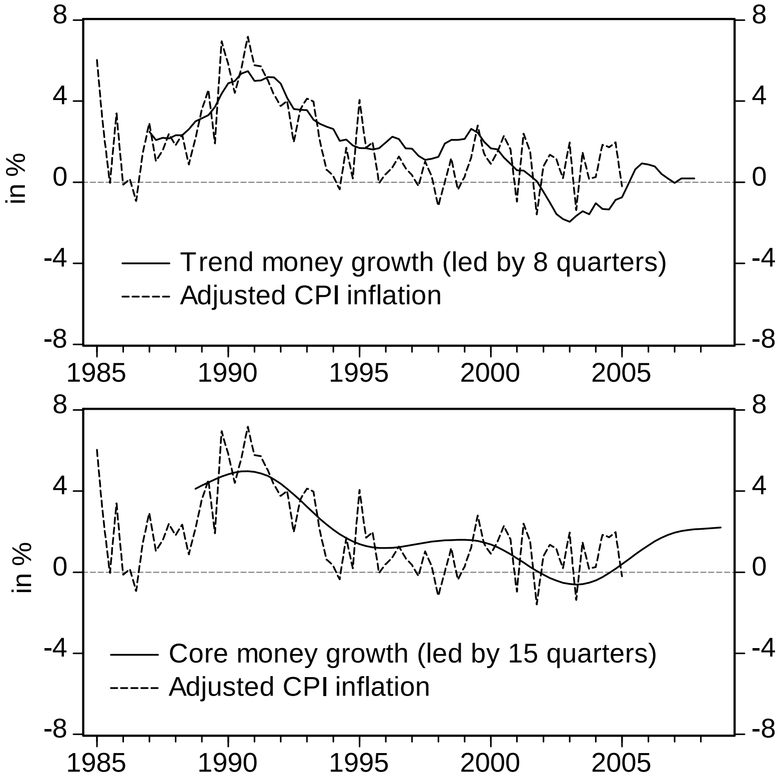
[15] From a forecasting point of view two-sided filters are less attractive since they attach a large weight to the last observation in sample. A second reason for preferring a one-sided filter is that future money growth may be correlated with future inflation, thereby exaggerating the correlation between 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.

[16] Neumann and Greiber [29] present estimations using alternative filters for $\overline{\mu}_t$ and find that the model is robust to such changes.

[17] 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.

[18] Inflation expectations in Neumann's model thus depend on money and potential output, whereas in Gerlach's model they are a function of money only (see footnote 13).

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.

parameter ϕ reflects the income elasticity. Combining equations (13) to (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 [32]). It has been argued that an elasticity greater than unity for broad monetary aggregates reflects that certain interest-rate bearing forms of money are held for portfolio considerations and thus grow faster than GDP (see e.g. Knell and Stix [23]).

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

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 neither considered by Gerlach nor by Neumann, seems weak in Switzerland.

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.

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			
	Normality (Jarque-Bera)	Fourth-order serial correlation	ARCH LM(1)
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).

7 Conclusions

This paper shows that a two-pillar Phillips curve, which originally was proposed by Gerlach [16] 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 a measure of 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 that are due to a change in the computation of the CPI in May 2000.

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 is probably due to the lower interest rate sensitivity of M3 and to the fact that nominal interest rates tended to decrease over the sample. The regressions suggest that inflation is driven by the output gap and a low-frequency component of money growth and that the long-run impact of the latter is unity.

As a robustness check, we also estimate the Phillips curve model proposed by Neumann [28]. 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 conclusion 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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