Central Banks' Inflation Forecasts: The Problem of Conditioning on Fixed Short-Term Interest Rates

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Abstract

It has become common practice for central banks to base their policy decisions on inflation forecasts and to use short-term interest rates as the main policy instrument. A widespread and seemingly straightforward way to address the question of whether short-term rates must be raised or lowered is to compute an inflation forecast conditioned on fixed short-term rates and to confront it with an inflation target or a less rigid definition of price stability.

Several authors have criticized such forecasts from the angle of communication and policy effectiveness. The focus of this paper is somewhat different. It mainly argues that conditioned inflation forecasts are problematic from a methodological point of view. First, as the assumption of fixed short-term rates will usually differ from historical policy behavior, the exercise is subject to the Lucas critique. One way to circumvent the critique is to say that conditioned inflation forecast show the hypothetical inflation path on the *proviso* that private agents continue to derive their expectations from an unchanged policy rule. This way, the Lucas critique is relegated to the set of assumptions underlying the forecast. In reality, however, the policy rule would presumably break down in the eyes of private agents if short-term rates were held fixed in situations that call for significant rate adjustments. Conditioned inflation forecasts thus tend to understate the inflationary or deflationary consequences of a hypothetical fixed-interest-rate policy. Second, the proviso of an unchanged policy rule can be implemented in different ways. For instance, private agents may be assumed to always anticipate policy actions as implied by the historical rule and get surprised again and again by short-term rates that are still unchanged. Or they may be assumed to correctly anticipate fixed short-term rates over the official forecast horizon, followed by a policy reaction according to the historical rule thereafter. These assumptions are largely arbitrary but – as shown in this paper – may affect the outcome of the inflation forecast to a sizable degree.

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1. Introduction

It has become common practice for central banks to base their policy decisions on *inflation forecasts*. The question of whether short-term rates should be raised or lowered is often addressed in terms of inflation forecasts computed on the assumption of constant short-term rates, usually (and somewhat misleadingly) called *conditioned* inflation forecasts. At first glance, this may appear as a straightforward thought experiment, showing how inflation would develop under constant short-term rates and thereby indicating whether a policy change is required. Many central banks carry out this type of exercise in the internal decision process and some, including the Swiss National Bank (SNB), also communicate policy decisions in such terms to the public.

This practice has recently been criticized with regard to transparency of central bank communication and policy effectiveness by Faust and Leeper (2005), Woodford (2005) and Archer (2004), among others. The perspective of this paper is somewhat different. The idea of figuring out how inflation would develop under constant short-term rates is taken as given (because board members find the question informative). It is then argued, however, that it is difficult to address the issue in a sensible way for methodological reasons. As the assumption of fixed short-term rates is likely to differ from historical policy behavior in most forecasting situations, the exercise is subject to the *Lucas critique*. Of course, one may circumvent the critique by saying that conditioned inflation forecasts show the hypothetical course of inflation on the *proviso* that private agents continue to form expectations on basis of an *unchanged policy rule*. In reality, however, the historical rule would presumably break down under a constant-interest-rate policy. Moreover, the proviso of an unchanged policy rule can be modeled in various ways, giving rise to quite different inflation forecasts.

These points are illustrated in the paper by means of a simple forward-looking "New Keynesian" model for the Swiss economy with reference to the forecasting situation faced by SNB in March 2004. The conclusion is that constant-interest-rate inflation forecasts are only transparent if the adopted assumptions regarding the formation of expectations are explicitly stated. In this sense, the paper is also about transparency of central bank communication. In relation to the existing literature, the main contribution of the paper is to show numerically how sensitive conditioned inflation forecasts are likely to be in a concrete forecasting situation.

Section 2 of the paper reviews the various problems surrounding conditioned inflation forecasts. *Section 3* outlines the model, which is described in detail the *Appendix*. *Section 4* presents, on basis of this model, different forms of conditioned inflation forecasts, distinguished by the way the proviso of an unchanged policy rule is implemented. *Section 5* summarizes and draws conclusions.

2. Constant-interest-rate inflation forecast and the formation of expectations

A conceivable form of inflation targeting is to set short-term rates at time t such that projected inflation hits the target at the forecasting horizon $t+k$ without any further rate adjustments. The problems associated with such a concept (time-inconsistency, multiple equilibria) are discussed in Leitemo (2003) and Honkapohja and Mitra (2003). To give a simple example, consider an economy that pulls out of a recession with a very low inflation rate. One may then figure out to what level the short-term rate has to be set in t in order to move inflation up to the target in $t+k$. However, as the economy is likely to gain momentum in the course of the forecast period, the inflation path resulting from this policy will probably be strongly convex, i.e. inflation crosses the target line at time $t+k$ with a steep slope. Somewhat later in the forecast period, say at time $t+0.5k$, and assuming that everything happens as projected, the same reasoning will lead to a different conclusion because at the new forecasting horizon, $t+1.5k$, inflation exceeds the target. Hence, the short-term rate must be raised in $t+0.5k$, which contradicts the constant-interest-rate assumption of the forecast made in period t. In other words, the concept is time-inconsistent. It almost necessarily leads to conclusions that invalidate earlier conclusions, even in a shock-free environment. There is one exception, namely in case of an inflation path that tends asymptotically to the target and remains there beyond the forecast horizon. But such a path is generally not attainable with a constant-interest-rate policy. Again taking the example of an economy that recovers from a recession, a policy that produces such a path is to raise short-term rates gradually. Compared to a constant-interest-rate policy leading to the same inflation rate at time $t+k$, short-term rates would thus be lower at the beginning and higher towards the end of the forecast period.

In fact, most central banks do adjust short-term rates *gradually*. In such strategies, conditioned inflation forecasts do still play a role, but it is of different nature. As the short-term rate is fixed at the level of the current decision, the projected inflation rate will generally deviate from the target towards the end of forecast horizon. This deviation is then used by the central bank to signal to the public that further rate changes have to be expected. One of the reasons why central banks like this concept is that communication can be limited to an explanation of the current decision while statements about future policy changes remain vague. The alternative of publishing a path for short-term rates is thought to involve too much commitment, cause unpleasant controversies about the conduct of monetary policy and harm credibility of the bank in case of subsequent deviations from a previously published path.

Whether these considerations are valid or not is controversial in the literature. Goodhart (2001) reviews the arguments against conditioned inflation forecasts but eventually defends the concept, mainly because constant short-term rates are clearly an assumption and not a rule and therefore not binding in case of future shocks. In contrast, Faust and Leeper (2005) regard conditioned inflation forecast as messages that are "shrouded in an obscure code" and difficult to understand for the public. They stress the superiority of forecasts with endogenous short-term rates in a theoretical model of agents with imperfect knowledge. In their opinion, central banks could enhance transparency decisively by communicating their own assessment of the appropriate path of short-term rates. Archer (2004) and Woodford (2005) share this view and extend the argument along the following lines: The task of monetary policy is essentially to shape the formation of expectations as a basis for economic decision-making. The central bank can thus enhance the efficiency of policy by revealing the sequence of interest rate adjustments that seems most appropriate, given the currently available information. In contrast, communicating only the first step of this sequence as such is of negligible information content for economic decision-making.

One may note in this context that some central banks have recently moved away from constant-interest-rate inflation forecasts. The *Bank of England* and the *Sveriges Riksbank* publish inflation forecasts based on fixed as well as market expectations of short-term rates. In the past, the emphasis was on the former, but the practice has meanwhile changed in favor of projections based on markets expectations of short-term rates. See Bank of England (2004a) and Sveriges Riksbank (2005). Other central banks like the *Norges Bank* and the *Reserve Bank of New Zealand* publish inflation forecasts based on their own assessment of an appropriate path of short-term rates.

In relation to the aforementioned literature, the focus of this paper is narrower. It does not deal with issues like optimal communication strategies of central banks or the efficiency of monetary policy. The argument is simply that constant-interest-rate inflation forecasts involve several assumptions regarding the formation of expectations - both within and beyond the forecast horizon - that are largely arbitrary but nonetheless influence the outcome of the forecasts substantially. Therefore, such forecasts are only transparent if the underlying assumptions are outlined in detail. These points will be exemplified in what follows with reference to the forecasting situation faced by SNB in March 2004. At that time, the short-term interest rate (3M-Libor) was at a historical low of 0.25% while the Swiss economy was recovering from a recession and expected to gain momentum in the forecast period. However, as the output gap was still negative and inflation close to zero, the decision was to leave the 3M-Libor unchanged for the time being. Accordingly, the published forecast was conditioned on a constant 3M-Libor of 0.25%. On this assumption, inflation was predicted to increase to 3% over the three-year forecast horizon. Given the SNB's definition of price stability (inflation below 2%), the message of the forecast thus was that higher short-term rates had to be envisaged in the near future.

This example illustrates two points. First, if a forecast period is characterized by changing cyclical conditions, the constant-interest-rate assumption will not only deviate from normal policy behavior but may even result in an inflation forecast that conflicts with the banks commitment to preserve price stability. For such a forecast scenario, it is hard to deny the relevance of the *Lucas critique*. Second, one has to distinguish between the *thought experiment* of conditioned inflation forecasts and the *conclusion* drawn from them. While the conclusion may be that short-term rates must be raised or lowered, the conditioned forecasts should show what would happen to inflation if short-term rates were kept constant over the forecast horizon.

As pointed out by Lucas (1978), econometric forecasting models typically include empirical parameters that do not have a *deep* behavioral interpretation. Such parameters depend on the policy regime prevailing in the estimation period and thus are likely to drift away from their econometric estimates if the policy regime changes. The Lucas critique applies to conditioned inflation forecasts in an exemplary manner. Forecasts based on *VAR models*, for instance, extrapolate the empirical regularities in the interaction of economic variables into the future. One of these regularities is that short-term rates are raised in an upswing and lowered in a downswing. Keeping them fixed is technically straightforward: One introduces a series of appropriately calibrated shocks into the corresponding equation. But whether this produces reliable forecasts for the remaining variables is doubtful, in particular if the forecast period is characterized by changing cyclical conditions. In such situations, the shocks needed to keep short-term rates fixed are likely to become very large in relation to the historical distribution the shocks. Therefore, in the language of Leeper and Zha (2003), such *policy interventions* cannot be regarded as modest, so that sizable *expectations formation effects* come into play, making the forecast unreliable.[1]

In traditional *structural models* things are hardly any better. Holding short-term rates constant amounts to conditioning the forecast on a variable that in fact is endogenous and plays an important role in stabilizing the economy. Suppressing this mechanism may change the working of the whole system in an unpredictable way. For policy simulations to be reliable, the variable on which the model is conditioned must be *superexogenous* in the sense of Engle, Hendry and Richard (1983).

The Lucas critique may seem less relevant in models of the *DSGE* variety due to their emphasis on strict microfoundations. However, recent attempts to take these models closer to the data and use them as forecasting tools came at the cost of introducing some *ad hoc* elements as well.[2] For example, in the widely used *Calvo* price-setting scheme the frequency by which firms re-optimize prices is measured by a constant parameter. This is problematic since in an optimizing framework the frequency of price changes should be related to the monetary policy regime, as discussed in Bakhshi, Khan and Rudolf (2004). Problems with regime-dependent parameters must also be expected in the new DSGE model of the Bank of England due to the data-analytic nature of its *non-core* part.[3] Moreover, while DSGE models may offer an

[1] According to Leeper and Zha (2003), a *modest policy intervention* is a change in policy consistent with the *historical variation* in policy under the prevailing regime. The authors develop a so-called *modesty statistic* in terms of shocks to the policy rule. As long as this statistic does not exceed a certain threshold value, agents can be assumed to stick to their views about the prevailing policy regime. Otherwise, changes in the formation of expectations will take place.

[2] See, e.g., Christiano, Eichenbaum and Evans (2001) or Smets and Wouters (2001, 2003).

[3] For a non-technical overview of the model, see Bank of England (2004b). A detailed description of the model is given by Harrison et. al. (2005). In particular, this paper explains the philosophy behind the distinction between the micro-theoretical *core-part* and the data-analytic *non-core* part.

ideal setting for analyzing alternative *well-defined* policy rules, it is difficult to see how they would satisfactorily cope with inflation forecasts in which the assumption of fixed short-term rates gets increasingly in conflict with the historical policy rule.

Of course, one may superficially comply with the Lucas critique by saying that conditioned inflation forecasts involve the proviso that private agents continue to believe in an *unchanged policy rule*. In reality, however, the historical policy rule would almost certainly break down in the eyes of private agents if short-term rates were held fixed in situations that call for significant policy changes. The proviso of an unchanged formation of expectations thus tends to dampen the reaction of inflation to the constant-interest-rate assumption, and relying on such forecasts may be quite dangerous. What central banks should like to know is how inflation would develop under constant short-term rates, *including* the impact of such a policy on the formation of expectations.

Moreover, the proviso of an unchanged policy rule can be modeled in different ways. Three scenarios will be considered in this paper. In a *first scenario*, the central bank announces (not in reality, but in the thought experiment of the forecast) that it will keep short-term rates fixed over the forecast horizon and revert to the historical reaction function thereafter. Private agents are assumed to regard this statement as credible, i.e. they correctly anticipate fixed short-term rates over the official forecast period as well as the subsequent resumption of the historical rule. The *second scenario* posits an *unshakable belief* of private agents in the historical policy rule, whatever policy actions they observe. On this assumption, private agents always expect changes in monetary policy as implied by the historical reaction function and get repeatedly surprised by short-term rates that are still left unchanged. In a *third scenario*, these surprises are assumed to feed into a *learning process* about future policy reactions. Although the three scenarios share the same constant-interest-rate assumption, the response of inflation will differ strongly, being weakest in the second case since private agents are assumed to wrongly count on pronounced stabilizing policy actions within the forecast period.

This section can be summarized as follows. *First*, inflation forecasts conditioned on constant short-term interest rates are subject to the Lucas critique. *Second*, the proviso that private agents continue to believe in an unchanged policy rule tends to dampen the inflation forecast in relation to what would happen in reality under fixed short-term interest rates. *Third*, the proviso of an unchanged policy rule can be implemented in different ways, giving rise to potentially quite different inflation forecasts.

3. A simple forward-looking "New Keynesian" model

A distinguishing feature of econometric forecasting models is the treatment of expectations. In models of the VAR variety, for example, expectations are taken into account only implicitly. To the extent that they mattered in the past, they can be assumed to be reflected somehow in the estimated parameters. But issues related to the formation of expectations cannot be addressed in such a framework. What is needed for an analysis of this sort is a model with explicit *forward-looking* elements.

The "New Keynesian"-type model used in the following fulfills this requirement.[4] It describes the interaction between the output gap, the inflation rate, the exchange rate and short and long-term interest rates in a forward-looking setting. Monetary policy is represented by a smoothed *Taylor rule*, according to which short-term interest rates react to *expected* inflation, the output gap, the change in the output gap and the change in the real exchange rate. Further forward-looking elements are show up in the equation for the output gap and the Phillips-curve in the form of *model-consistent expectations* of the corresponding dependent variable. In addition, the long-term interest rate is derived via the *term-structure hypothesis* from the expected path of short-term rates over a horizon of 40 quarters. This way, the future course of monetary policy is reflected in advance in the current long-term rate. Finally, long-term inflation expectations conform to the model's long-term inflation forecast. They are used to convert the nominal into the real long-term interest rate.

Another conceivable forward-looking element, *uncovered interest rate parity*, was not built into the model because the implied exchange rate jumps are strongly at odds with the data. What the data show is "delayed overshooting" in response to changes in the Swiss/foreign interest rate differential, and the exchange rate equation is specified such as to reproduce this behavior. The dependence of the Swiss economy on developments in the world economy is captured by *three exogenous variables*, namely the foreign output gap, the foreign inflation rate and the foreign short-term interest rate. A more detailed discussion of the model is provided in the *Appendix*.

Data definitions are also given in the Appendix. In short, domestic and foreign output gaps are computed as HP-detrended real GDPs. Foreign GDP includes the European Union, the United States and Japan, with weights reflecting the orientation of Swiss exports. Short-term interest rates are measured as 3-month money market rates, and the long-term rate is the 10-year government bond rate. Foreign and Swiss price developments are measured as CPIs. The *exchange rate* is defined as Euro/Swiss franc, so that an increase corresponds to an appreciation. Empirically, expressing the exchange rate of the Swiss franc vis-à-vis the Euro only works better than using a trade-weighted effective exchange rate, presumably because Swiss exports to other world regions compete not so much with home producers in those regions but rather with exports from other European countries.

When the model is used for forecasting, one has to decide in one way or another on the future course of the three exogenous variables. In a concrete forecasting situation, one might rely on world economy scenarios as provided by the OECD or the IMF. Here, the development of the three foreign variables is simply derived from a VAR with two lags. In order to exclude earlier periods with relatively high inflation rates,

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[4] The model was specifically constructed for the purpose of this paper and was not included in the suite of models underlying the SNB's inflation forecasts of March 2004. Similar forward-looking models are used by other central banks for discussing monetary policy issues.

the estimation period of the VAR is confined to 1995q1 to 2005q1. Within this period, the three foreign variables can be regarded as roughly stationary. Starting from any given cyclical situation, the estimated VAR converges with strongly dampened oscillations to a *steady state*, characterized by an output gap of zero, an inflation rate of 1.9% and a short-term interest rate of 3.9%, implying a real short-term rate of 2%.

The model for Switzerland has a well-defined steady state as well. The output gap is closed, the inflation rate is 1% (as defined by the target in the Taylor rule), the real long-term interest rate is 2.4% (consistent with a closed output gap) and the real short-term rate is 1.4% (0.6 percentage points below the foreign real short-term rate, reflecting the well-known Swiss interest-rate advantage). Nominal long and short-term rates exceed their real counterparts by the steady-state inflation rate. Finally, given a foreign/Swiss inflation differential of 0.9 percentage points in steady state, the nominal exchange rate appreciates by 0.9% per annum, so that the real exchange rate remains constant.

The following forecasting exercise is designed to replicate the situation faced by SNB in March 2004. Disregarding potential data revisions and publication lags, it is assumed that actual data were available for all variables of the model up to 2003q4, so that the forecast starts in 2004q1. At that time, the SBN was quite optimistic about the future development of the world economy. Growth in the European Union, which had been weak for two years, was predicted to pick up, and the US economy was assumed to proceed with strong growth into the forecast period. On these exogenous assumptions, Swiss GDP growth, which already had turned positive in the second half of 2003, was expected to gain further strength in the forecast period.

The "New Keynesian" model, combined with the VAR approach for the exogenous variables, produces a quite similar (and in retrospective too optimistic) forecast scenario. *Figure 1* shows the VAR forecast for the three exogenous variables. The foreign output gap, which was negative in 2002 and 2003, turns positive in 2004 and peaks at 0.4% in 2005q1. CPI-inflation in the Euro area increases to 2.1% in 2004q2 and remains slightly above 2% for almost three years. The Euro short-term interest rate is successively raised to a peak of 4% in 2006. In the long run, the three foreign variables converge to the aforementioned steady-state values of zero for the output gap, 1.9% for the Euro inflation rate and 3.9% for the Euro short-term interest rate.

Figure 1: VAR-forecast for the foreign variables (2004q1 – 2009q4)

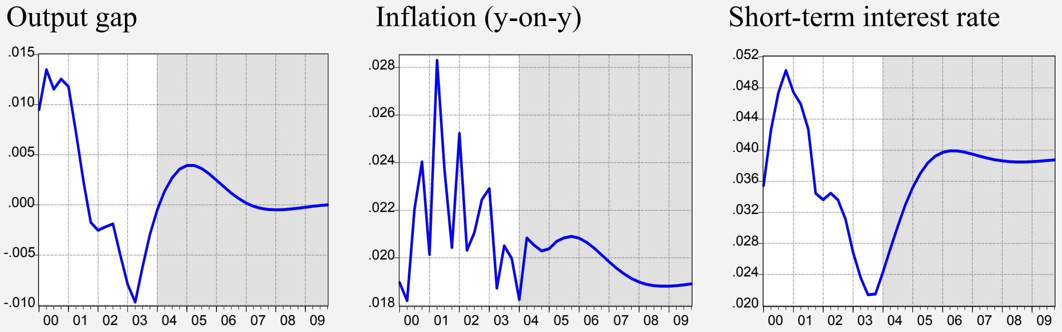

Figure 2: Baseline forecast for Switzerland (2004q1 – 2009q4)

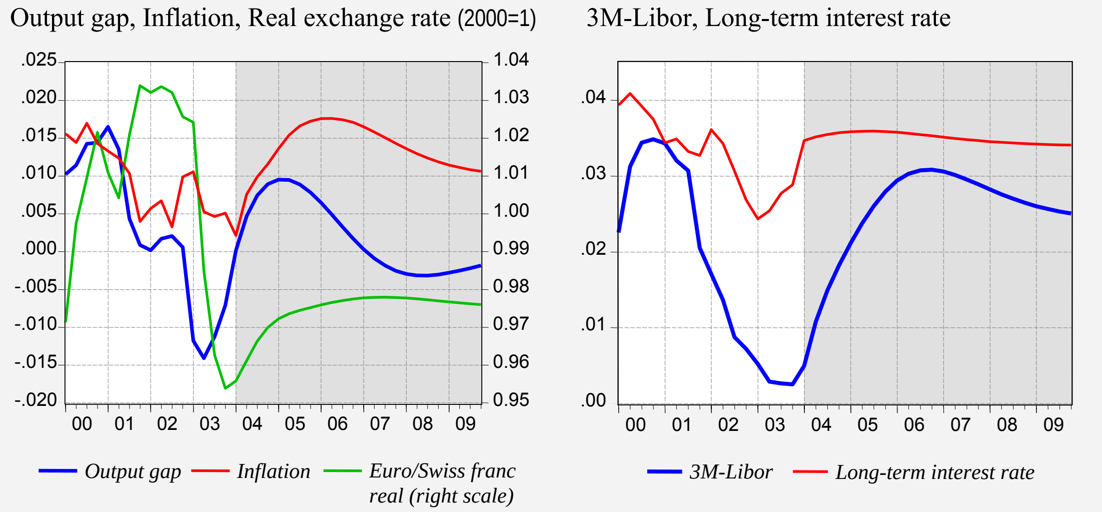

Figure 2 shows the resulting forecast for Switzerland. The output gap turns positive in 2004 and peaks at 1% in 2005q2. Inflation is driven up from 0.2% at the beginning of the forecast period to 1.7% in 2006. The response of monetary policy is to raise short-term rates (3M-Libor) continuously from 0.25% to 3.1% in 2006. Long-term interest rates anticipate the increase in short-term rates and move up immediately by 0.5 percentage points to 3.5%. As monetary policy is tightened somewhat more resolutely than in the Euro area, the Swiss franc appreciates by about 2% in real terms. This *unconditional* forecast will henceforth be referred to as BASE.[5]

The SNB's published inflation forecast of March 2004 differs from BASE in two respects. First, it was derived as a consensus from a suite of models, not including the model used here. Second, as the decision was to leave the 3M-Libor unchanged for the time being, the forecast was conditioned on a constant 3M-Libor of 0.25% over the entire forecast period. It is mainly for this latter reason that inflation rises more strongly in the official forecast than in BASE, reaching 3% at the end of the official forecast horizon (2006q4). When commenting the forecast, the SNB did not elaborate on the assumptions made with respect to the formation of expectations. Of course, communicating such issues would not be easy. From a methodological point of view, however, it is important to note that the outcome of the forecast depends on these assumptions. This will be shown next.

[5] In a forward-looking model, the forecast horizon is theoretically infinite since the solution of the model for period *t* always depends on solutions beyond period *t*. A standard technique to handle this problem is to impose the steady-state solution of the model as a *terminal condition* and to shift this condition so far to the future that the behavior of the model in the period of interest becomes practically independent of it. This is the solution method adopted here.

4. Inflation forecasts under alternative expectation schemes

4.1 Constant short-term rates expected in the forecast period, followed by corrective measures thereafter

A first forecast scenario corresponds to the following thought experiment. In March 2004, SNB announces that it will keep the 3M-Libor constant at 0.25% until the end of the forecast period (2006q4) and revert to the historical reaction function thereafter. Private agents regard this announcement as credible. They are also assumed to be familiar with the historical reaction function, which is a smoothed Taylor rule. The smoothing parameter $\lambda = 0.15$ implies that about half of a desired long-run change in short-term rates is completed within 4 quarters.[6] If the 3M-Libor is fixed for three years at 0.25%, the economy ends up overheated. How should monetary policy be expected to behave in such a situation? On the one hand, a radical policy change may seem required in order to break the inflationary trend. On the other hand, a sudden jump in short-term rates by several percentage points would be unprecedented in history and might cause disturbances in the economy that are difficult to assess. In other words, private agents may find reasonable arguments for expecting less or more pronounced interest rate smoothing after the period with fixed short-term rates. To allow for these possibilities, three different forecast versions are simulated:

- In SIM1a, private agents expect the historical Taylor rule with $\lambda = 0.15$ to be resumed in 2007q1. This produces a steep increase in the 3M-Libor.
- In SIM1b, parameter λ is reduced to 0.05. This implies that private agents regard a more gradual tightening of monetary policy as more plausible.
- In SIM1c, λ is raised to 0.5. This triggers an increase in the 3M-Libor that is even steeper than in SIM1a, implying that private agents expect radical corrective measures to be taken in 2007q1.

The three simulations thus illustrate to what extent the conditioned inflation forecast depends on different assumptions about expected monetary policy *beyond* the official forecast horizon. The results are shown in *Figure 3*, where the official forecast period (2004q1-2006q4) is indicated by the shaded areas.

For all three versions of the Taylor rule, monetary policy is substantially tightened after the official forecast period. The 3M-Libor rises to peak values of about 7%. This increase takes place within 7 quarters in SIM1a, 12 quarters in SIM1b and 3 quarters in SIM1c. In the long run, the 3M-Libor tends back to the path of BASE in all three cases, reaching it in 2015 (outside the graph).

The strongest overheating of the economy is observed in SIM1b (gradual tightening after the official forecast period), with inflation at 12.4% and the output gap at 4.0% in 2006q4. In SIM1c (radical tightening), inflation is at 7.6% and the output gap at 2.5% in 2006q4. In SIM1a (normal tightening), the respective numbers are 9.2% and

6 With this value of λ, the Taylor rule reproduces the historical behavior of monetary policy quite closely; see Appendix, Figures A3 and A4.

3.0%. Hence, even though the 3M-Libor is identically fixed at 0.25% until 2006q4 in the three forecasts, they differ strongly already within the official forecast period. Moreover, they show much higher inflation than the official forecast (3% in 2006q4).

Where do the differences between SIM1a, SIM1b and SIM1c come from? *First*, since output and price-setting decisions are forward-looking, the anticipated policy reaction beyond the official forecast period matters for developments within it. The extent to which this mechanism is at work can be demonstrated by making the model less forward looking. The weights for the forward and backward-looking terms used so far are 0.4 and 0.6 in the output gap equation and 0.55 and 0.45 in the Phillips curve equation.[7] If the SIM1b-forecast is recomputed with weights of 0.2 and 0.8 in both equations, inflation increases only to 3.2% instead of 12.4%. Hence, by reducing the degree to which private agents are assumed to be forward-looking, one obtains an inflation forecast that comes much closer to the SNB's official forecast, suggesting that the official forecast gave little weight to forward-looking behavior.

Second, the derivation of the long-term interest rate via the term-structure hypothesis introduces another forward-looking element. As shown in Figure 3c, the *nominal long-term interest rate* exceeds the BASE path in all SIM1-forecasts, even though the short-term rate is fixed at 0.25% until 2006q4. Moreover, the highest values of the long-term interest rate are recorded in SIM1b, where monetary policy is tightened relatively slowly after the official forecast period. At first sight, these results may seem somewhat surprising. But the average value of expected short-term rates over the relevant 10-year horizon is highest in SIM1b, followed by SIM1a, SIM1c and BASE, because postponing monetary tightening causes higher inflation and thus must be followed by a prolonged period with relatively high short-term rates in order to bring inflation back to target.

Considering *real long-term rates* (Figure 3e) the picture is reversed. In the SIM1b-forecast, *long-term inflation expectations* are by far highest (Figure 3d) so that the real long-term rate is pushed down most strongly (even though the nominal long-term rate is highest in this scenario). In other words, the less speedy monetary tightening is expected to be *beyond* the forecast period, the higher are long-term inflation expectations and the lower is the real long-term rate. Hence, the strongest stimulus on the economy is observed in SIM1b. At the other extreme is SIM1c, where the fall in the real long-term rate is less pronounced and the stimulus on the economy thus relatively weak.

All SIM1-forecasts are based on the proviso that central bank statements are *fully credible*. In reality, however, fixing short-term rates at 0.25% during an economic upswing might undermine the credibility of the central bank. The likelihood that this happens can be assessed on basis of the *shocks* required in the Taylor rule in order to freeze the 3M-Libor at 0.25%. These shocks become bigger and bigger over the

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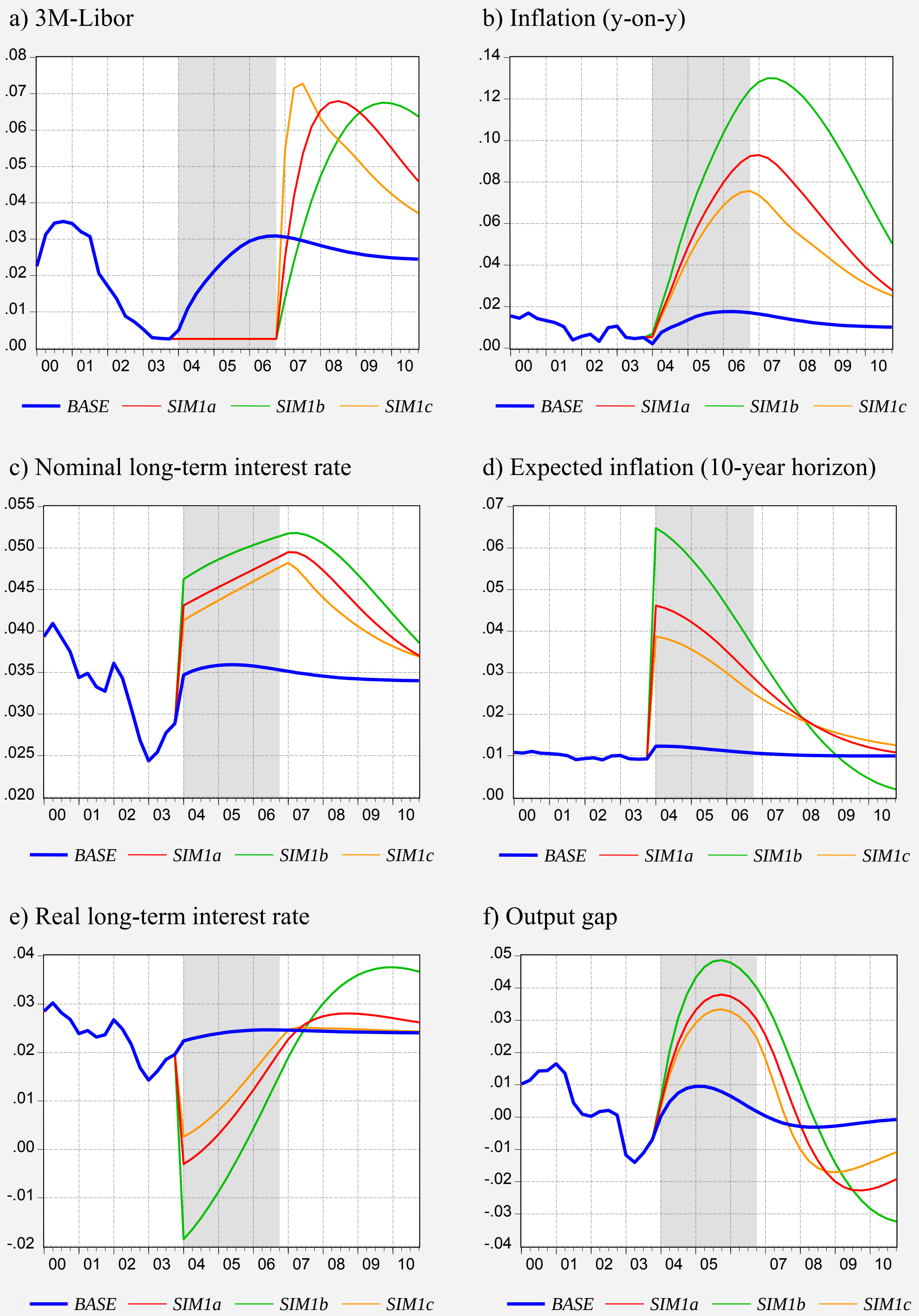
[7] As shown in the Appendix, this ensures a good historical fit of the model.

Figure 3: Conditioned inflation forecast (SIM1) – 3M-Libor correctly anticipated

3M-Libor fixed at 0.25% until 2006q4, then Taylor rule resumed with different λ's.
SIM1a: $\lambda = 0.15$ SIM1b: $\lambda = 0.05$ SIM1c: $\lambda = 0.5$
BASE: original Taylor rule ($\lambda = 0.15$) from the beginning of the forecast period



forecast period. They get as large as 3.6 times the estimated standard error of the equation towards the end of the forecast horizon, corresponding to a P-value of only 0.0002 for a single shock and much less for the whole series of shocks. Hence, a survival of the historical policy rule in the eyes of private agents seems quite unlikely under a policy that holds the 3M-Libor constant at 0.25%.

In loose terms, one may argue that a changed perception of monetary policy is taken into account in the SIM1b-forecast to some extent since the reduced value of λ can interpreted as a slow movement back to the historical policy rule. In this sense, the SIM1b-forecast can be considered the most realistic one. Given the steep increase in inflation to 12.4%, the message of this forecast is that postponing monetary tightening could be very hazardous - in contrast to the SNB's official forecast, where the slow increase of inflation to 3% over the three-year forecasting horizon suggests that there is some room for a "wait-and-see" policy.

4.2 Monetary tightening expected within the forecast period

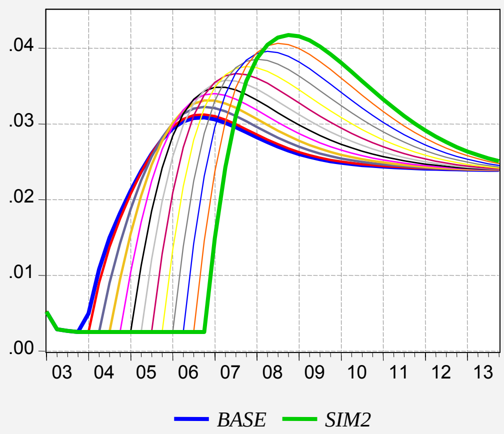
An alternative forecast scenario can be designed as follows. The 3M-Libor is fixed at 0.25% until 2006q4, exactly as in the previous exercise, but private agents are now assumed to expect monetary tightening in each quarter of the forecast period, as implied by the historical reaction function, even though they get repeatedly surprised by an unchanged 3M-Libor. This scenario, which posits an absolutely *ironclad belief of agents in the historical policy rule*, is referred to in the following as SIM2. It comes much closer to the SNB's official inflation forecast than the above SIM1-forecasts.

As shown in *Figure 4*, the expected upward moves in the 3M-Libor become bigger and bigger over the forecast period since the economy gets increasingly overheated. Although these policy reactions do not actually materialize (until 2007q1 when the historical rule is resumed), they feed into long-term rates. The value of the long-term rate in period *j* is derived from a sequence of short-term rates over 40 quarters. The first value in this sequence is 0.25%, the known value of the 3M-Libor in period *j*, followed by 39 expected values that are substantially higher. The long-term interest rate expected in period *j* for period *j*+1 moves up a bit since the relevant sequence of short-term rates does no longer start with 0.25% but with the higher value expected for period *j*+1. When period *j*+1 arrives, the 3M-Libor on the one hand turns out to be unchanged at 0.25%. On the other hand, the anticipated increase in the 3M-Libor gets even stronger. This second effect dominates, so that the starting points of the expected development of long-term rates are repeatedly revised upwards, as shown in Figure 4.

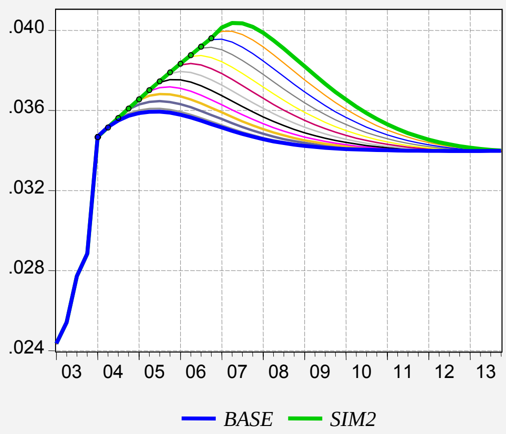
The SIM2-forecast for the long-term interest rate corresponds to the collection of the starting points of the 12 curves in Figure 4b. It lies above the BASE path, even though the 3M-Libor is fixed at 0.25% until 2006q4. As in the previous SIM1-forecasts, since delayed monetary tightening entails higher inflation rates, it must be followed by a prolonged period with relatively high short-term interest rates, to the effect that the nominal long-term rate is not lower but higher than in BASE. However, the deviation from the BASE path is much smaller than in the SIM1-forecasts.

Figure 4: Interest rate expectations in SIM2-forecast after $j = 1$ to 12 periods with 3M-Libor = 0.25% (thin lines) and final forecast paths (green lines)

a) 3M-Libor



b) Long-term interest rate



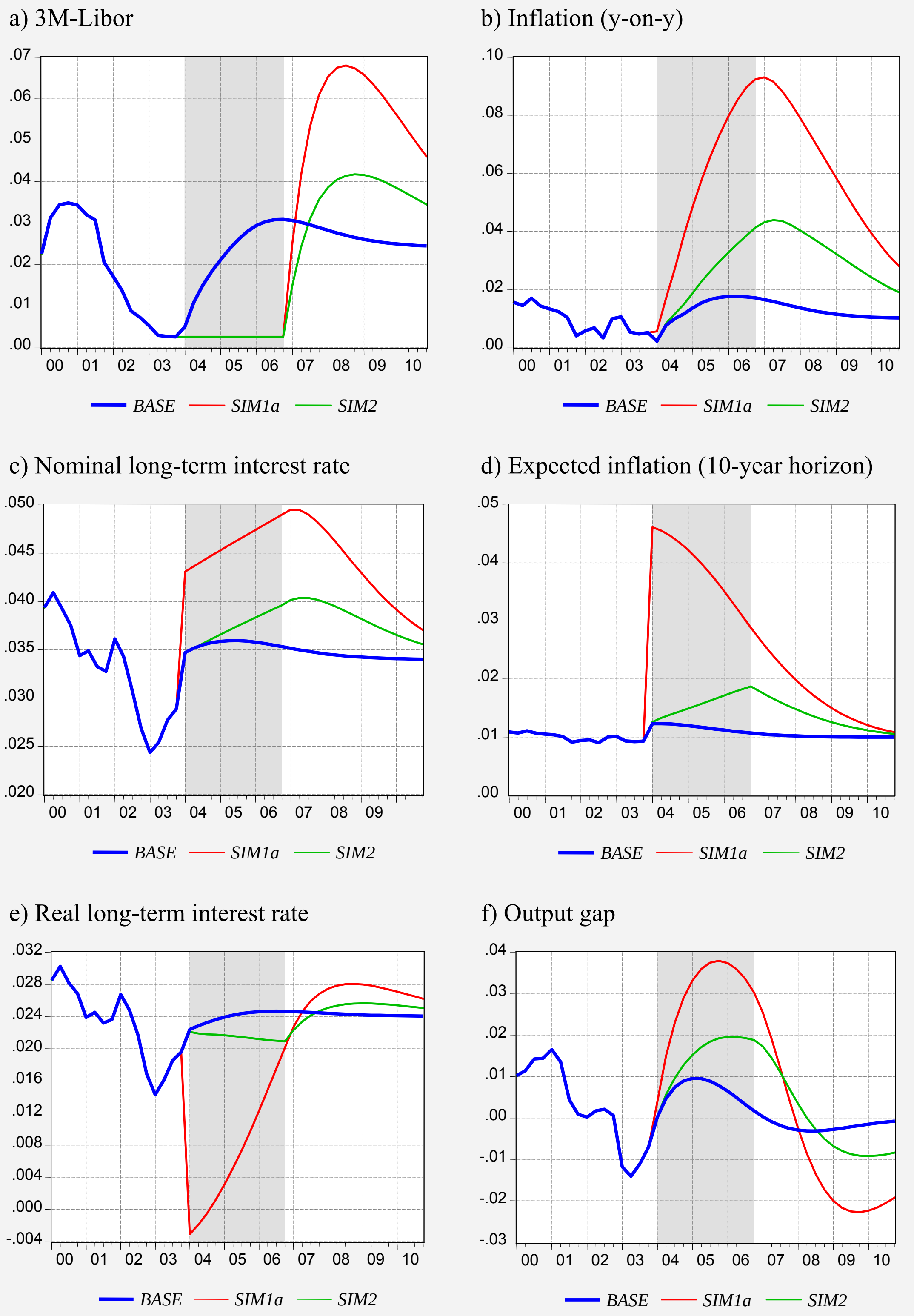
The results of the SIM2-forecast are shown in *Figure 5*, along with the previous SIM1a- and BASE-forecast. The differences between SIM2 and SIM1a are large. In particular, inflation expectations remain relatively tame in SIM2 because private agents always expect monetary tightening. As shown in Figure 5d, while *long-term inflation expectations* jump up to 4.6% at the beginning of the forecast period in SIM1a (upon the "announcement" of the constant-interest-rate policy), they tend slowly to 2% in the SIM2-forecast. As a result, the *real long-term rate*, which drops to negative values in SIM1a, is only slightly reduced in SIM2 (Figure 5e), even though the *nominal long-term rate* is pushed up by less (Figure 5c). Similarly, the *real exchange rate* (not shown in the graph) depreciates both in SIM1a and SIM2, but the effect is smaller in SIM2, again due to the fact that private agents are assumed to expect monetary tightening within the forecast period. Given a weaker reduction in the real long-term interest rate and less pronounced depreciation of the Swiss franc, the stimulation of the economy remains relatively modest in SIM2. The output gap peaks at 2%, compared with 4% in SIM1a (Figure 5f), and the inflation rate increases to 4.1%, compared with 9.2% in SIM1a (Figure 5b).

An even more pronounced inflationary boom was produced in the previous SIM1b-forecast on the assumption that private agents expect only gradual tightening of monetary policy at the end of the official forecast horizon. In this scenario, inflation rises to 12.4%. On the other hand, the SIM1-forecasts can be made much less inflationary by assuming that private agents are only weakly forward-looking. As also shown above, if the SIM1b-forecast is recomputed on such an assumption, inflation increases to 3.2% only instead of 12.4%. Hence, very different inflation forecasts can

Figure 5: Conditioned inflation forecast (SIM2) – Monetary tightening expected within the forecast period

SIM2: 3M-Libor = 0.25% until 2006q4, but private agents expect monetary tightening in each quarter of the forecast period.

BASE and SIM1a reproduced from Figure 3.



be produced under the same constant-interest-rate assumption, depending on how the formation of private agents' expectations is specified. The SNB's official forecast of March 2004 was conditioned on a 3M-Libor of 0.25% as well and showed an increase in inflation to 3%. This suggests that the official forecast was either based on (implicit) assumptions similar those of the SIM2-forecast (where the constant-interest-rate assumption does not feed into inflation expectations), or that the underlying models assumed a behavior of private agents that is largely backward-looking (as in the recomputed SIM1b-forecast). It follows that inflation forecasts conditioned on constant short-term interest rates are only transparent if the underlying assumptions with respect to the formation of expectations are clearly spelled out.

4.3 Deviations from the policy rule feed into a recursive learning process

In the previous SIM2 forecast, private agents continue to believe in the historical policy rule, even though they get repeatedly surprised by an unchanged 3M-Libor of 0.25%. If conditioned inflation forecasts are meant to show what would happen in reality under constant short-term rates, this assumption is hardly appropriate because rational agents would presumably learn from past surprises and change their expectations about future policy reactions accordingly.

There are many ways to model such a *learning process*. In any case, the input to this process consists of the observed deviations of the 3M-Libor from the path implied by the historical Taylor rule. Confronted with these deviations, private agents might conclude that the central bank pursues a higher inflation target. Being familiar with the model, they could for instance figure out period for period the inflation target that makes the Taylor rule compatible with observed policy behavior. On this assumption, long-term inflation expectations would increase strongly, giving rise to a much higher inflation forecast. However, the notion that agents infer a fundamental change in the policy rule from just a few additional observations may seem too extreme. Another possibility is to assume that private agents change their view about the prevailing policy rule gradually, for instance in the form of a temporary deviation from historical behavior. In this case, long-term inflation expectations remain anchored by the historical Taylor rule and projected inflation increases only moderately.

Denoting the sequence of shocks to the historical Taylor rule required to freeze the 3M-Libor in the forecast period at 0.25% by u_t, private agents might forecast these shocks recursively on basis of an estimated AR(1) process:

(1) $u_t = \rho u_{t-1} + \varepsilon_t$ or (2) $u_t = \alpha + \rho u_{t-1} + \varepsilon_t$

Historically (1981q1–2003q4), the residuals of the Taylor rule show an insignificant autocorrelation of $\rho = 0.16$ (and of course a zero mean, i.e. $\mu = \alpha/(1-\rho) = 0$). Hence, at the beginning of the forecast period, there is no reason for private agents to extrapolate non-zero residuals into the forecast period. In the course of the forecast period, however, a series of consistently negative shocks to the Taylor rule is observed, entailing higher and more significant estimates of ρ, so that subsequent deviations from historical policy behavior might be forecasted on basis of (1) or (2).

In more detail, the assumed learning process can be described as follows. In each quarter of the forecast period, private agents observe an unchanged 3M-Libor of 0.25%. They solve the model for the shock to the Taylor rule that produces this outcome, append this shock to the existing vector of residuals, estimate (1) or (2) and augment the Taylor rule by the estimated shock process. Although the expected sequence of shocks will affect the solution of the model in the following quarter, it may again indicate monetary tightening, whereas the actually observed 3M-Libor remains unchanged. The agents then solve the model again for the shock to the Taylor rule that produces this outcome, add the shock to the existing vector of shocks, re-estimate (1) or (2), etc.

How many of the historical residuals should be used in the estimation of (1) or (2)? If the shocks computed for the forecast period were appended to the entire vector of historical residuals (1981q1–2003q4), the estimates of ρ and α would remain close to zero. However, any test of parameter stability would indicate a structural break, thus suggesting that the relevant parameter values should be derived from a reduced sample. In the following, it is assumed (somewhat arbitrarily) that the shock process is estimated on basis of a rolling sample of 24 quarters in (1) and 28 quarters in (2). So, for example, in the first quarter of the forecast period (2004q1), the sample used to estimate (1) consists of 23 historical residuals (1998q2– 2003q4) and the shock computed for 2004q1. In the final quarter of the forecast period (2006q4), the sample consists of 12 historical residuals and 12 recursively computed shocks.

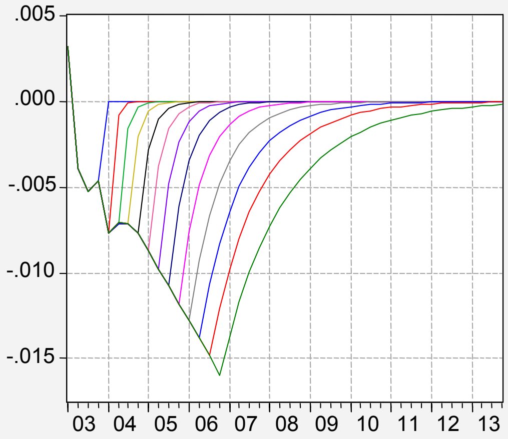
The resulting inflation forecasts differ strongly depending on whether (1) or (2) is used. The two forecast scenarios are denoted by SIM3a and SIM3b, respectively:

- SIM3a: As shown in *Figure 6a*, the expected shocks decay to zero (since the recursive estimates of ρ remain smaller than 1). In other words, agents expect negative deviations from the historical Taylor rule that are only temporary. For example, the shock to the Taylor rule computed for the last quarter of the forecast period (2006q1) amounts to -1.6 percentage points, and this shock is extrapolated into the future with a ρ of 0.85 so that it decays to zero rather slowly. Earlier shocks are smaller and – given lower estimates of ρ – decay more quickly.
- SIM3b: As shown in *Figure 6b*, the shocks decay to a negative constant, given by $\mu = \alpha/(1-\rho)$, where $\alpha < 0$ and $0 < \rho < 1$. This means that agents anticipate negative deviations from the historical Taylor rule that persist ad infinitum. Considering the form of the Taylor rule – see equation (3) in the Appendix – deducting a constant from is tantamount to a permanent upward shift in the central bank's inflation target. Interestingly, as inflation increases much more in this case, the shocks to the Taylor rule required to keep the 3M-Libor at 0.25% become substantially bigger over the forecast period in comparison with SIM3a.

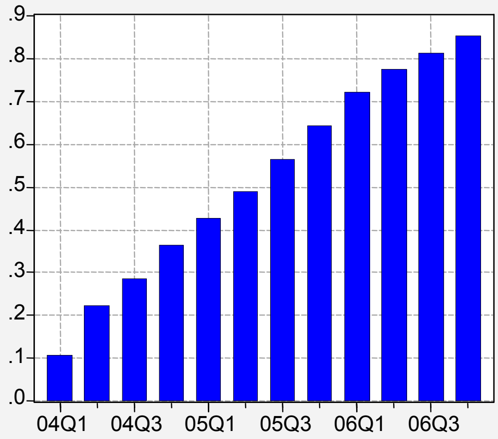
Figure 6: Shocks to the Taylor rule required to keep the 3M-Libor at 0.25% in the forecast period and extrapolation based on recursively estimated AR(1) processes

a) SIM3a: zero-mean AR(1) process – equation (1)

Shocks and shock forecasts

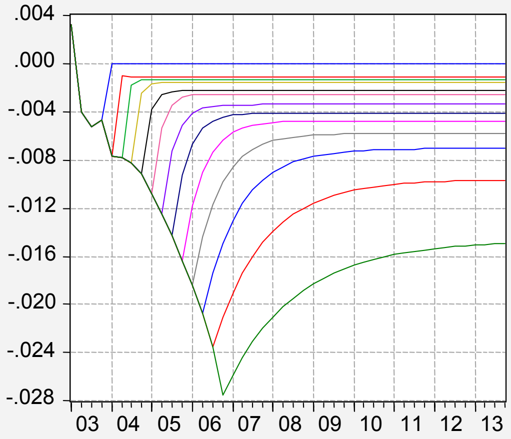


Recursive estimates of ρ



b) SIM3b: nonzero-mean AR(1) process – equation (2)

Shocks and shock forecasts



Recursive estimates of α and ρ

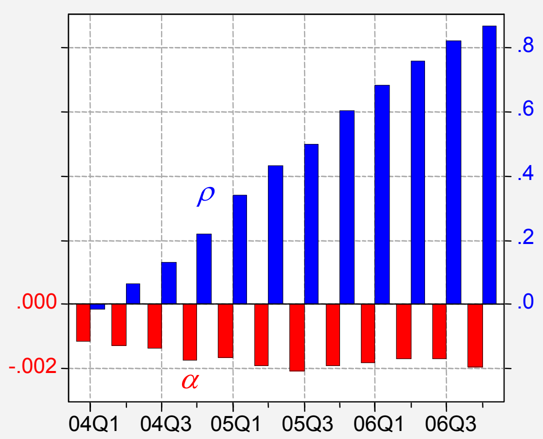


Figure 7 shows the expected upward moves of the 3M-Libor and the eventual policy reaction at the end of the official forecast horizon for SIM3a (agents expect temporary deviations from the historical Taylor rule) and for SIM3b (agents expect permanent deviations from the Taylor rule). As can be seen in comparison with Figure 4a, the learning process underlying SIM3a has only moderate implications for the expected and final policy reactions. Nevertheless, even though monetary policy is initially expected to get tightened by somewhat less, higher inflation is eventually reflected in a higher and not a lower short-term rate. This mechanism becomes much more pronounced under the learning process of SIM3b. In this case, the 3M-Libor increases to about 11% outside the official forecast horizon. In the long run, the 3M-Libor tends to 10%.

Figure 7: Interest rate expectations in SIM3-forecast after *j* = 1 to 12 periods with 3M-Libor = 0.25% (thin lines) and final forecast path (green line)

a) Shocks to the Taylor rule extrapolated with zero-mean AR(1)

b) Shocks to the Taylor rule extrapolated with nonzero-mean AR(1)

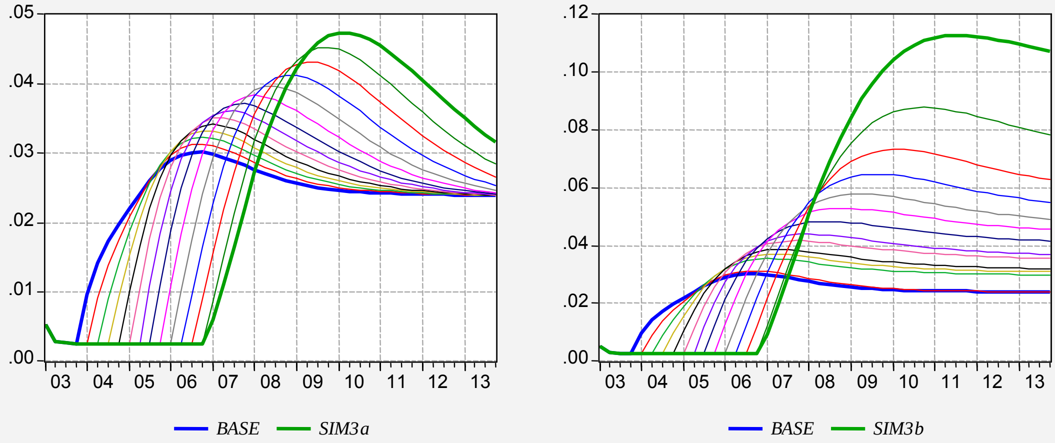


Figure 8 compares inflation expectations (10-year horizon) and corresponding inflation forecasts across scenarios. The figure reproduces the BASE scenario (normal policy reaction from the beginning of the forecast period) and the SIM2 scenario (3M-Libor fixed until 2006q4, but agents always expect monetary tightening as implied by the historical Taylor rule) and compares them with SIM3a (3M-Libor fixed until 2006q4, agents anticipate temporary deviations from the Taylor rule) and SIM3b (3M-Libor fixed until 2006q4, agents anticipate permanent deviations from the Taylor rule). The differences between SIM3a and SIM2 are rather small. Hence, as long as inflation expectations remain anchored by a fundamentally unchanged policy rule, temporary deviations from it – even if anticipated by private agents to some extent – have only a weak impact on the inflation forecast. In SIM3a, inflation increases to 4.6% at the end of the official forecast horizon (shaded area), compared to 4.1% in SIM2. Long-term inflation expectations move to maximum of 2.6% in SIM3a, compared to 1.9% in SIM2. In contrast to these rather small differences, a drastically higher inflation forecast is obtained if the learning process leads to the perception of a changed inflation target of the central bank. In this case, as simulated in SIM3b, long-term inflation expectations move up to almost 10% and tend back only slightly to about 8.5% in the long run (corresponding to agents' perception of a higher inflation target). At the end of the forecast horizon (2006q4), forecasted inflation is at 7.1%.

The real short-term rate tends to 1.4% in all forecast scenarios in the long run. With the exception of SIM3b, this results from a combination of a nominal short-term rate of 2.4% and an inflation rate of 1%. In SIM3b, the same real short-term rate of 1.4% results from a nominal short-term rate that converges to 10% and an inflation rate that converges to 8.6%. As a consequence of the increased inflation target, no attempt is made in SIM3b to reduce inflation. Of course, the central bank might surprise private agents after the official forecast horizon in the other direction by setting short-term rates higher than expected, at the cost of a temporarily strongly negative output gap.

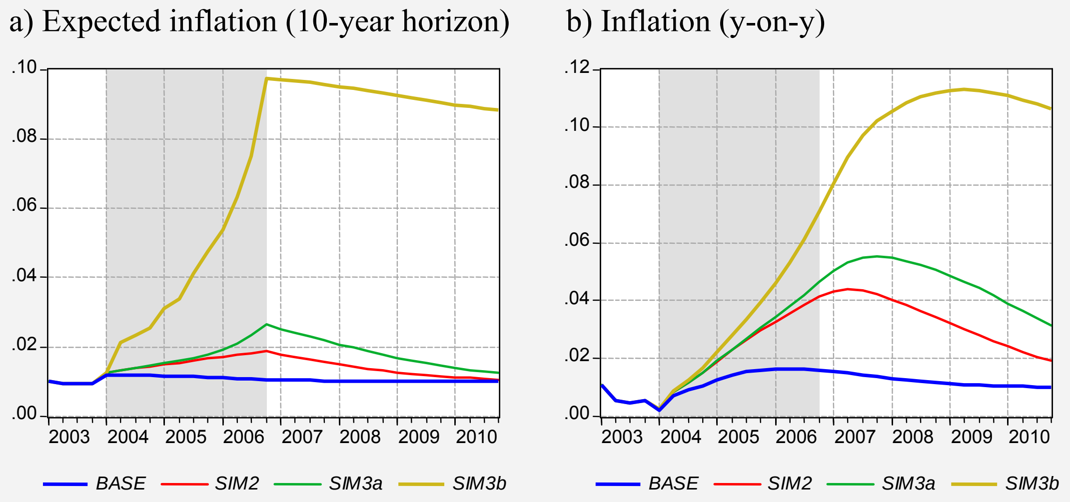
Figure 8: Expected inflation and inflation forecast in different scenarios

BASE: Normal policy reaction from the beginning of the forecast period

SIM2: 3M-Libor fixed until 2006q4, but agents believe in an unchanged policy rule

SIM3a: 3M-Libor fixed until 2006q4, agents expect temporary deviations from the policy rule

SIM3b: 3M-Libor fixed until 2006q4, agents expect persisting deviations from the policy rule



5. Conclusion

Most central banks base their policy decisions on inflation forecasts and use short-term interest rates as the main policy instrument. Within this concept, inflation at a certain forecast horizon can be viewed as a function of past, current and future short-term rates and many other factors that are not controlled by the central bank. Given a hopefully correct assessment of these factors, the task of monetary policy is to decide on a time path for short-term rates such that inflation remains low and stable. A simplified alternative to such a dynamic control exercise is to compute inflation forecasts conditioned on constant short-term rates and to infer from the outcome whether short-term rates must be raised or lowered in order to maintain price stability. Many central banks rely on such conditioned inflation forecasts in the internal decision process, and some also publish them in order to explain policy decisions to the public. However, a closer look at the underlying assumptions regarding the *formation of expectations* reveals that conditioned inflation forecasts are problematic.

This is exemplified in this paper on basis of a small "New Keynesian" model for the Swiss economy with reference to the forecasting situation faced by Swiss National

Bank in March 2004. The example is admittedly rather extreme since in March 2004 short-term rates were at a historical low of 0.25% while the economy was recovering from a recession and expected to gain momentum in the forecast period. In such a situation, the normal policy behavior is to continually raise short-term rates instead of holding them fixed. Due to this discrepancy, it is difficult to specify how private agents form their expectations. Moreover, depending on the concrete choice of these assumptions, quite different inflation forecasts can be produced. The following three options were considered in this paper:

- SIM1-forecast: Private agents are assumed to anticipate fixed short-term rates over the official forecast horizon, followed by a more or less speedy resumption of the historical reaction function thereafter. In this case, inflation expectations increase strongly and the real long-term rate falls substantially, resulting in a strong stimulus on the economy and thus a high inflation forecast.
- SIM2-forecasts: Private agents are assumed to form expectation on basis of the historical reaction function throughout the forecast period. They thus always expect monetary tightening and get surprised again and again by short-term rates that are still left unchanged. In this case, inflation expectations remain relatively tame and the real long-term interest rate is reduced only slightly, resulting in a weak stimulus on the economy and thus a low inflation forecast.
- SIM3-forecast: Private agents get surprised by unchanged short-term rates, as in SIM2, but these surprises feed into a learning process. The resulting inflation forecast then strongly depends on whether the learning process gives rise to anticipated deviations from the historical policy rule that are only temporary or persistent (in the sense of a changed inflation target). In the first case (SIM3a), the inflation forecast differs only by little from SIM2. In the second case (SIM3b), a much higher inflation forecast is obtained.

According to the model used in this paper, inflation increases to values between 3.2% and 12.4% in these scenarios, depending on the speed by which monetary policy is expected to get tightened after the official forecast period, the degree to which private agents are assumed to be forward-looking, and the assumed form of the learning process. Hence, very different inflation forecasts can be obtained under the same constant-interest-rate assumption. Conditioned inflation forecasts are therefore only transparent if the adopted assumptions regarding the formation of expectations are explicitly spelled out.

Moreover, the assumptions underlying conditioned inflation forecasts tend to be *hybrid* in a rather disturbing way: On the one hand, the forecasts are computed on the assumption of constant short-term rates – with the aim to point out the inflationary or deflationary consequences of such a policy. On the other hand, the forecasts may involve (explicitly or implicitly) the proviso that the historical policy rule survives in the eyes of private agents – which dampens the reaction of inflation. Therefore, it may be quite dangerous to base policy decisions on such forecasts. Given the outcome that inflation would increase only moderately even if short-term rates were kept low over a prolonged period of time, one might wrongly infer that monetary tightening could be postponed for at least some quarters without jeopardizing price stability. As a corollary, one might also underestimate the size of the interest rate adjustment required to bring inflation into line with the definition of price stability.

One of the reasons why central banks prefer constant-interest-rate inflation forecasts is that communication to the public can be limited to an explanation of the current decision while statements about future policy changes remain vague. The alternative of publishing a path for short-term rates is thought to involve too much commitment, cause unpleasant controversies about the conduct of monetary policy and harm credibility of the bank in case of subsequent deviations from the published path.

On the other hand, the commitment associated with the publication of an interest-rate path could be mitigated by emphasizing the various risks surrounding the forecast, as is done, e.g., by the *Reserve Bank of New Zealand* and the *Norges Bank*. Another option is to condition the inflation forecast on *market expectations of short-term rates*. This alternative, which is practiced by the *Bank of England* and the *Swedish Riksbank*, may appear quite attractive. *First*, market expectations of short-term rates are derived from information that is generally available. By conditioning the forecast on this information, the central bank does thus not reveal anything new to the markets. *Second*, the path of short-term rates as expected by the markets does not have to correspond to what is regarded as optimal by the central bank. Hence, there is no commitment to stick to such a path, and subsequent revisions just reflect a changed view of the markets anyway. *Third*, while market expectations do not have to coincide with the reaction function in the forecasting models used by central banks, the differences are probably not too big. Some of the problems discussed in this paper might therefore disappear or at least become less severe. From a methodological point of view, however, any inflation forecast conditioned on an exogenously assumed policy path is problematical. Moreover, as pointed out by Blinder (1998) and Woodford (2005), incorporating market expectations into an inflation forecast may create some new problems, in particular if the central bank disagrees with the markets. In such situations, the central bank should not "confirm" the markets but rather take the lead in anchoring expectations.

APPENDIX: A "New Keynesian" model for Switzerland

The forecasting simulations in this paper are based on a forward-looking "New Keynesian" model for Switzerland. The model describes the interactions between the output gap, the inflation rate, the exchange rate and short and long-term interest rates on a quarterly basis, conditional on three exogenous variables, namely the foreign output gap, the foreign inflation rate and the foreign short-term interest rate. Similar models are widely used by central banks and other institutions for studying monetary policy and business cycle issues. See McCallum and Nelson (1999) for a theoretical foundation of this type of model.

Forecasts for the three exogenous variables of the model are obtained from a simple VAR with two lags. In order to exclude earlier periods with relatively high inflation and interest rates, the estimation period of the VAR is confined to 1995q1 to 2005q1. Within this period, the three variables can be regarded as roughly stationary. Starting from any given cyclical situation, the VAR converges to a steady state, characterized by an output gap of zero, an inflation rate of 1.9% and a nominal (real) short-term interest rate of 3.9% (2.0%). These steady-state values of the foreign variables have to kept in mind when calibrating the model for Switzerland.

The parameters of the model for Switzerland are partly set to plausible values and partly estimated. A detailed discussion of how these values were obtained is beyond the scope of the paper. It will be shown, however, that the model is able to reproduce the actual behavior of the Swiss economy with reasonable accuracy. The equations of the model are specified as follows.

The *output gap* (y) depends on the output gap in the previous quarter and the output gap expected for the next quarter. Driving variables are the foreign output gap (y^*), the real long-term interest rate (rlr) and the real exchange rate (er):

$$y_t = \beta\left(\beta^b y_{t-1} + (1-\beta^b) y^e_{t+1}\right) + \beta^* y^*_t + \beta^r (rlr_{t-1} - rlr^o) + \beta^e \ln\left(er_t / er^o_t\right) \qquad (1)$$

$$\beta = 0.9 \quad \beta^b = 0.6 \quad \beta^* = 0.25 \quad \beta^r = -0.1 \quad \beta^e = -0.1 \quad rlr^o = 0.024$$

Equation (1) can be viewed as the *IS curve* of the model. The degree to which output decisions are forward-looking is measured by $(1-\beta^b)$. er^o_t is the steady-state value of the real exchange rate (see below) and rlr^o= 2.4% is the value of the real long-term interest rate that is consistent with a zero output gap in steady state.

The *inflation rate* (π) depends on a lag structure of past inflation rates and the inflation rate expected for next period. Driving variables are the output gap and the change in the real exchange rate:

$$\pi_t = \gamma^b \left(\gamma^l \pi_{t-1} + (1-\gamma^l) \sum_{i=2}^{10} \pi_{t-i}/9 \right) + \left(1-\gamma^b\right) \pi^e_{t+1} + \gamma^y y_t + \gamma^e \Delta \ln(er_t) \qquad (2)$$

$$\gamma^b = 0.45 \quad \gamma^l = 0.5 \quad \gamma^y = 0.25 \quad \gamma^e = -0.2$$

Equation (2) is the *Phillips curve* of the model. The extent to which inflation formation is forward-looking is measured by $(1-\gamma^b)$. The weights of past and future inflation add up to 1. Hence, looking at the equation separately and disregarding the exchange rate term, a positive (negative) output gap would trigger an ongoing increase (decrease) in inflation. In other words, the Phillips curve is vertical in the long-run at an output gap of zero.

The *short-term interest rate* (*rs*) is determined by a *Taylor rule*. The explanatory variables are expected inflation in next period, the output gap, the change in the output gap and the change in the real exchange rate. The equation is specified in the form of a partial adjustment model in order to allow for interest-rate smoothing:

$$rs_t = \lambda\Big(rsr^o + \pi^e_{t+1} + \alpha^p\big(\pi^e_{t+1} - \pi^o_t\big) + \alpha^y y_t + \alpha^g \Delta y_t + \alpha^e \Delta\ln(er_t)\Big) + (1-\lambda)\, rs_{t-1} \qquad (3)$$

$$\lambda = 0.15 \quad rsr^o = 0.014 \quad \alpha^p = 0.5 \quad \alpha^y = 0.75 \quad \alpha^g = 1.0 \quad \alpha^e = -0.3$$

$rsr^o = 1.4\%$ is the steady-state value of the real short-term interest rate. It corresponds to the trend growth rate of real GDP in the period 1980-2004 and is 0.6 percentage points below the steady-state value of the foreign real short-term rate (as implied by the VAR for the three exogenous variables). The inflation target π^o_t is assumed to shift down from 3% in the 1980's and early 1990's to 1% thereafter (see below). The equation fits Swiss data best if λ is set to a relatively small value of 0.15 (pronounced interest-rate smoothing) and the coefficient on the output gap, α^y, is set to a relatively large value of 0.75 (compared to the usual Taylor rule value of 0.5).

The exchange rate is defined in the model in the form of foreign/domestic currency, so that an increase indicates an appreciation of the Swiss franc. For the reasons mentioned in the main text, the *exchange rate* equation is not based on UIP but rather data-oriented. The change in the nominal exchange rate, $\Delta\ln(e)$, is made dependent on an autoregressive term and the differential between domestic and foreign real short-term interest rates. In addition, the lagged level of the real exchange rate (*er*) in relation to its equilibrium value (er^o) is included in the sense of an error-correction mechanism:

$$\Delta\ln(e_t) = \delta^o + \delta^\rho \Delta\ln(e_{t-1}) + \delta^r\Big(rs_t - \pi_t - (rs^*_t - \pi^*_t) + \delta^b\Big) + \delta^e \ln\Big(er_{t-1}/er^o_{t-1}\Big) \quad (4)$$

$$\delta^o = 0.001575 \quad \delta^\rho = 0.3 \quad \delta^r = 0.2 \quad \delta^b = 0.006 \quad \delta^e = -0.3$$

According to this equation, a relative tightening of Swiss monetary policy entails an appreciation of the Swiss franc, followed by a movement back to a value that is determined by purchasing power parity (since er_t must converge to er_t^o in the long run). The value of δ^o is dictated by steady-state considerations: If domestic and foreign real interest rates are equal (up to the historical differential δ^b) and the real exchange rate is at its steady-state value, the nominal exchange rate must appreciate by the foreign/Swiss inflation differential. Hence, $\delta^o = (1-\delta^\rho)\,(\pi^* - \pi^o)$, where $\pi^* = 0.019$ (according to the VAR for the foreign variables) and $\pi^o = 0.010$ (inflation target in the Taylor rule). If δ^o were set to zero instead, the required appreciation of the nominal exchange rate in steady state would have to be brought about by a real exchange rate that lies constantly somewhat below its equilibrium value.

The *long-term interest rate* (*rl*) is defined, according to the term-structure hypothesis, as an average of expected short-term rates over a horizon of 40 quarters plus a constant κ (liquidity premium):

$$rl_t = \sum_{i=0}^{39} rs_i^e / 40 + \kappa \qquad \kappa = 0.01 \tag{5}$$

The value of κ is consistent with the difference between the steady-state value of the real long-term rate appearing in the output gap equation (rlr^o = 2.4%) and the steady-state value of the real short-term rate appearing in the Taylor rule (rsr^o = 1.4%).

The nominal long-term interest rate (*rl*) is converted into the real long-term rate (*rlr*) by deducting expected inflation with a conforming horizon of 40 quarters (π^{el}):

$$rlr_t = rl_t - \pi_t^{el} \qquad \pi_t^{el} = \sum_{i=1}^{40} \pi_i^e / 40 \tag{6}$$

Finally, the real exchange rate is defined as

$$er_t = e_t \frac{p_t}{p_t^*} \tag{7}$$

and the price level and the annualized quarterly inflation rate are linked by

$$\pi_t = 4\,\Delta\ln(p_t) \ . \tag{8}$$

Not part of the model, but sometimes in the foreground of policy discussions is the annual inflation rate, which can be appended to the model as

$$\pi 4_t = \ln\left(p_t / p_{t-4}\right) \tag{9}$$

Swiss and foreign short-term interest rates are measured as 3-month money market rates (Libor), and the Swiss long-term interest rate is the 10-year government bond rate. Domestic and foreign price levels and inflation rates are measured as CPIs. The *real exchange rate* is accordingly defined in terms of relative CPIs in the form of an external value, so that an increase in the variable reflects a real appreciation of the Swiss franc. Domestic and foreign output gaps are computed as HP-detrended real GDPs. The foreign GDP includes the European Union, the United States and Japan, with weights of 0.7, 0.2 and 0.1, respectively, reflecting the orientation of Swiss exports. In some contrast, the exchange rate of the Swiss franc is measured against the Euro only (the German Mark prior to 1999). Empirically, this works better than using a trade-weighted exchange rate, presumably because Swiss exports to other world regions compete not so much with home producers in those regions but rather with exports from other European countries. Accordingly, the foreign short-term interest rate appearing in the exchange rate equation also refers to the Euro area (Germany prior to 1999).

There is a certain tension between the set-up of the model and the actual development of the Swiss economy in two respects. *First*, the inflation rate according to the model must be stationary around the target value imbedded in the Taylor rule. Empirically, however, inflation was notably higher in the 1980's and the early 1990's than more recently. Therefore, in order to make the model data-consistent, we let the inflation target in the Taylor rule, π_t^o, decrease from 3% in the earlier period to 1% thereafter, as shown in Figure A1. *Second*, there was a pronounced upward trend in the real exchange rate in the 1980's that leveled off in the 1990's, as shown in Figure A2. Therefore, the steady-state value of the real exchange rate cannot be treated as a constant historically. This is taken into account in the output gap and exchange rate equation of the model by measuring the real exchange rate (er_t) in relation to its trend (er_t^O), which is computed via the HP-filter but replaced from 1993 onwards by a constant. These two amendments of the model only matter with respect the historical fit. In the forecast exercises reported in the main part of this paper, which start at the beginning of 2004, the inflation target is constant at 1% and the steady-state value of the real exchange rate is constant as well (at the value shown in Figure A2).[8]

Figure A1: CPI inflation

π, $\pi 4$: Inflation rate (q-on-q, y-on-y)

π^{o}: Inflation target in Taylor rule

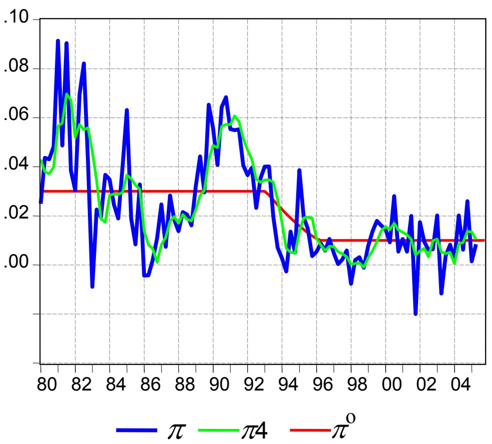
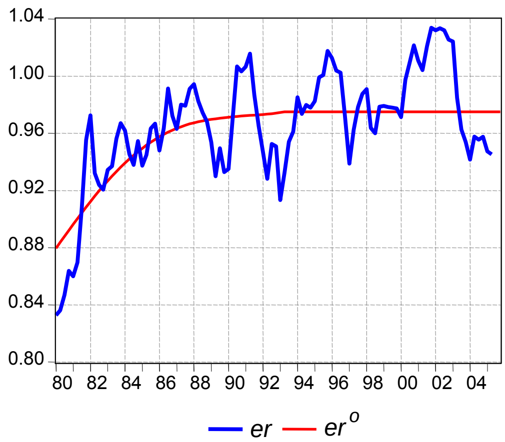


Figure A2: Real exchange rate

Euro/Swiss franc (2000=1) and Trend



One way to judge to performance of the complete model is to run a long-run dynamic simulation, conditional on the actual values of the exogenous variables. For the inflation rate and the short-term interest rate, the accordance between simulated and actual developments is quite satisfactory, as shown in Figure A3. For the output gap, the dynamic fit is somewhat better, whereas the exchange rate and the long-term interest rate are reproduced with much less accuracy. The exchange rate movements are captured by the model quite appropriately in the medium term (to the extent that they were caused by changing interest rate and inflation differentials), but the

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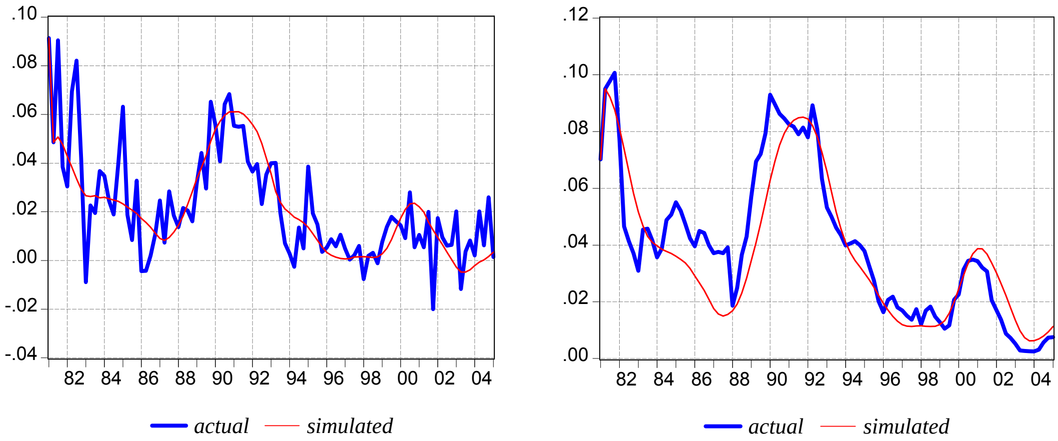
[8] Instead of assuming a constant equilibrium real exchange rate from 1993 onwards, one might also gather an ongoing, albeit much weaker trend appreciation in recent years and extrapolate that trend into the forecast period. In the context of this paper, the consequences would be minor, though.

sometimes large exchange rate shocks are of course absent from the simulation. The simulated path for the long-term interest rate lies constantly above actual values in the 1980's and below them in the 1990's. This is also not surprising. The simulated long-term interest rate is derived from the forecasted development of short-term rates, conditional on the *actual values of the exogenous variables* of the model. In contrast, private agents were not equipped with this information and thus were unable to foresee the strong increase in short-term rates towards the end of the 1980's and their strong decline in the course of the 1990's.

Figure A3: Dynamic model simulation

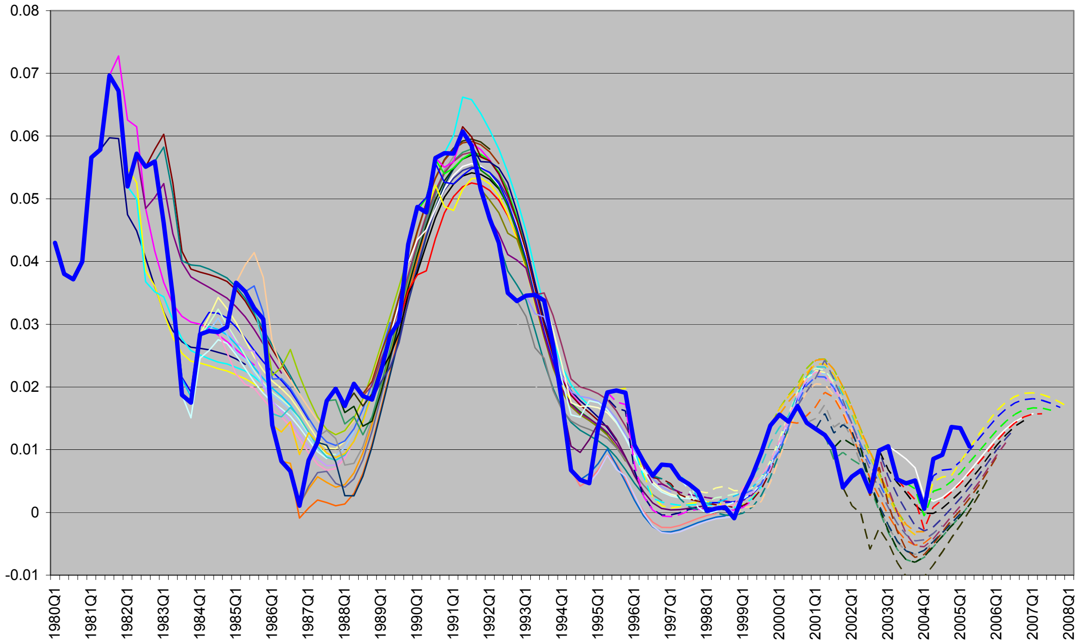
Inflation rate π (q-on-q, annualized) Short-term interest rate *rs*



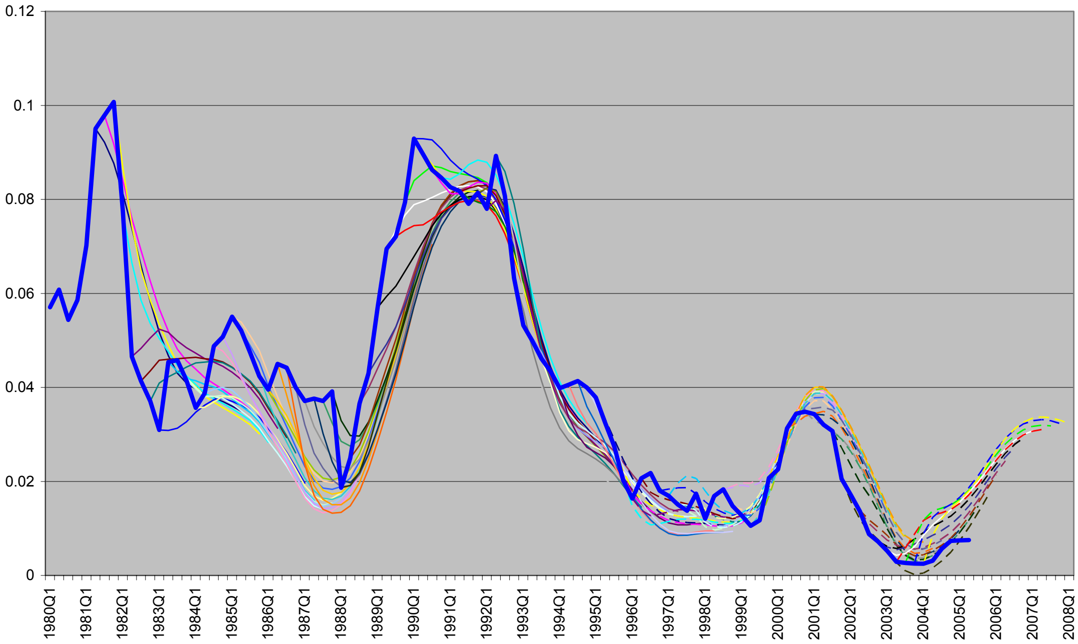
Another check of the model is to compute a series of short-run forecasts and to compare them with actual developments at various forecast horizons. The first forecast starts in 1981q3, the second one in 1981q4 and the last one in 2004q2, and each forecast covers 16 quarters. The 92 inflation forecasts obtained this way are depicted in Figure A4 (panel a), along with the corresponding paths of short-term interest rates (panel b). As data are available until 2005q1, the last forecast, starting in 2004q2, can be compared with actual realizations only up to the 4-quarter horizon. The average forecast error (RMSE) for the inflation rate remains somewhat below one percentage point at all forecast horizons. For the 3M-Libor, the forecast errors are slightly larger. When interpreting these numbers, one has to keep in mind that the forecasts are computed on basis of the actual values of the three exogenous variables. Therefore, the exercise is not representative for real forecasting situations, in which the world economy variables would be subject to forecast errors as well and one might moreover use less informed parameter values. What the exercise shows, however, is that the model is well-suited for the analysis of this paper. Given a correct assessment of the foreign variables, it quite realistically predicts the ups and downs in the inflation rate and the corresponding reactions of monetary policy. Somewhat disturbing in this respect is the fact that the model tends to overstate the cyclical swings in inflation in recent years. Of course, one could re-calibrate the model such that inflation would become less cyclical, for instance by lowering γ^l and γ^y. Whether the empirical evidence for a reduced volatility of inflation (relative to the driving forces) is strong enough to justify such a "quick fix" is questionable, though.

Figure A4: Forecasts over 16 quarters (starting in 1981q3, 1981q4, … 2004q2) and actual values (thick blue lines)

a) Inflation rate (y-on-y)



b) Short-term interest rate



Root-mean-squared forecast errors in percentage points

Forecast horizon (quarters)	*1*	*2*	*3*	*4*	*8*	*12*	*16*
Inflation rate	0.37	0.62	0.81	0.96	0.75	0.71	0.78
Short-term interest rate	0.58	0.86	1.00	1.12	1.16	1.21	1.12

Figure A5 shows *impulse-response functions* of the model for four types of shocks, a demand shock (output gap), a supply shock (Phillips curve), a monetary policy shock (Taylor rule) and an exchange rate shock. The demand shock and the exchange rate shock are introduced as one percentage point perturbations of the respective equation in a single quarter. In case of the supply shock and the monetary policy shock, it makes more sense to equally distribute the shocks over four quarters (0.25 percentage points in each quarter). All shocks are introduced as positive disturbances, so that they correspond to a positive demand shock, an adverse supply shock, a tightening of monetary policy and an appreciation of the Swiss franc, respectively.

Demand shock (panel a): The initial reaction of the output gap (1.3 PP) is somewhat larger than the shock itself, which is due to the forward-looking character of the model. On impact, inflation increases by 0.6 PP and the short-term interest rate by slightly less, so that the real short-term rate falls a bit initially. In the following quarters, however, inflation tends back to the baseline more quickly than the short-term rate, so that the response of the real short-term rate becomes positive, reflecting a tightening of monetary policy. The long-term interest rate is lifted by about 0.1 PP. As the reaction of long-term inflation expectations is smaller, the real long-term rate goes somewhat up as well. Higher inflation entails a persistent depreciation in the nominal exchange rate but – due to monetary tightening - a temporary appreciation in the real exchange rate. In the long run, all variables return to their baseline values, expect the price level and the nominal exchange rate, which show permanent deviations from the baseline of about +0.9% and –0.9%, respectively.

Supply shock (panel b): Inflation is pushed up by about 0.8 PP (slightly less than the sum of the shocks in the four quarters) and the output gap falls with a some delay by about 0.2 PP. In this dilemma situation, the reaction of monetary policy is to raise short-term rates, initially by less than the increase in inflation but by the 5th quarter by slightly more, so that the real short-term rate goes up a bit, indicating a somewhat more restrictive policy stance. The real long-term rate ($rl - \pi^{el}$) is also slightly raised. Higher inflation is largely mirrored by a nominal depreciation of the Swiss franc (notice that $\Delta \ln(e)$ is not annualized whereas π is). Hence, the real exchange rate increases only by little. In the long run, all variables return to their baseline values, expect the price level and the nominal exchange rate, which show permanent deviations from the baseline of about +1.2% and −1.2%, respectively.

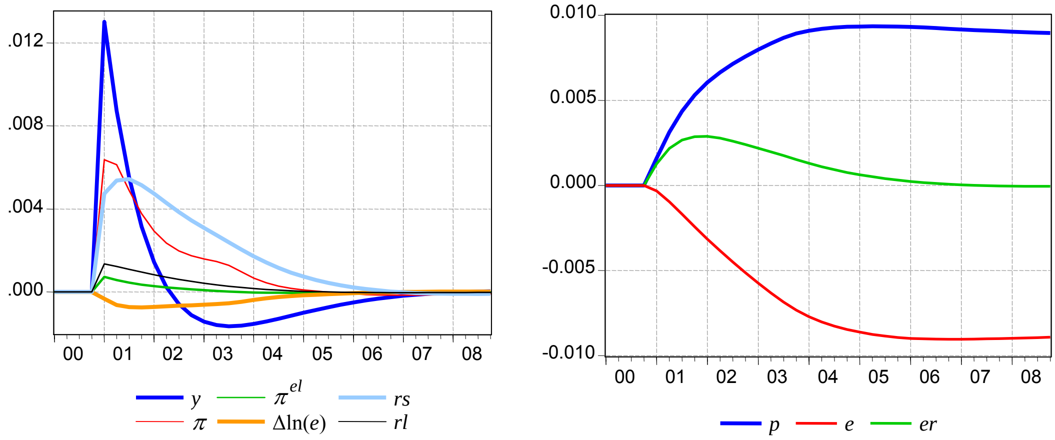
Money shock (panel c): The money shock amounts to an increase in short-term rates of about 0.5 PP over four quarters. Inflation is reduced with a short lag by 0.3 PP, and the output gap decreases by some 0.2 PP. Interestingly, long-term interest rates show a weak negative response. The reason is that the initial period with higher short-term rates entails a persistent decrease in inflation and therefore is overcompensated by subsequently lower short-term rates. However, the decline in the long-term rate is smaller than the decline in long-term inflation expectations, so that real long-term interest rate moves up, especially at the beginning of the simulation. The real exchange rate increases by a maximum of about 0.3% but tends back to the baseline in the long run, as the fall in the price level by 1.2% is just matched by a nominal appreciation of 1.2%.

Exchange rate shock (panel d): The exchange rate shock reduces inflation and - with a short lag - the output gap by about 0.3 PP. The monetary reaction is to cut short-term rates by some 0.3 PP. As inflation reverts to the baseline rather quickly, the real short-term rate is lowered. Similarly, long-term inflation expectations fall by less than long-term interest rates, so that the real long-term rate is lowered a bit as well. In the long run, all variables tend back to the baseline, except the price level and the nominal exchange rate, which show lasting deviations from the baseline of –0.4% and +0.4%, respectively.

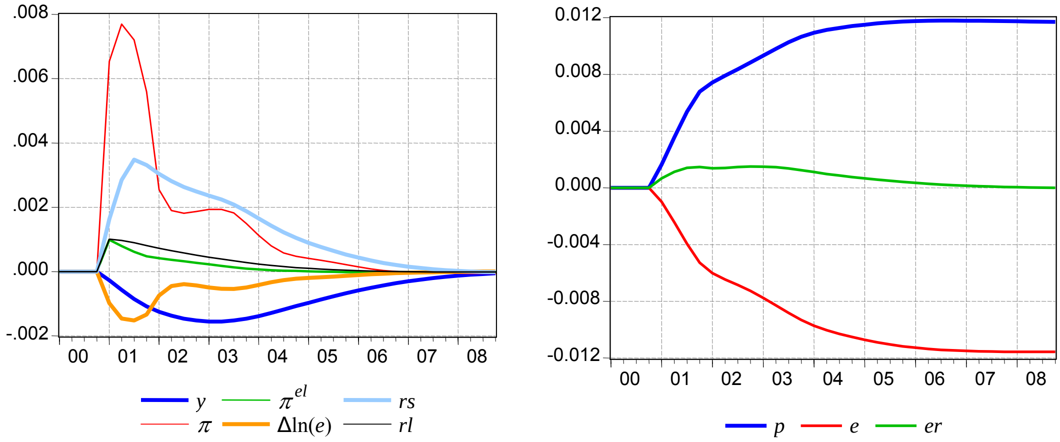
Figure A5: Impulse-response functions (shown over a 8-year horizon)

y Output gap	π Inflation rate	π^{el} Long-term inflation expectations
p Price level	rs Short-term interest rate	rl Long-term interest rate
e Nominal exchange rate	er Real exchange rate	$\Delta\ln(e)$ Relative change in e

a) Demand shock (adding a 1 PP shock to the Output gap equation)



b) Supply shock (adding four 0.25 PP shocks to the Phillips curve)



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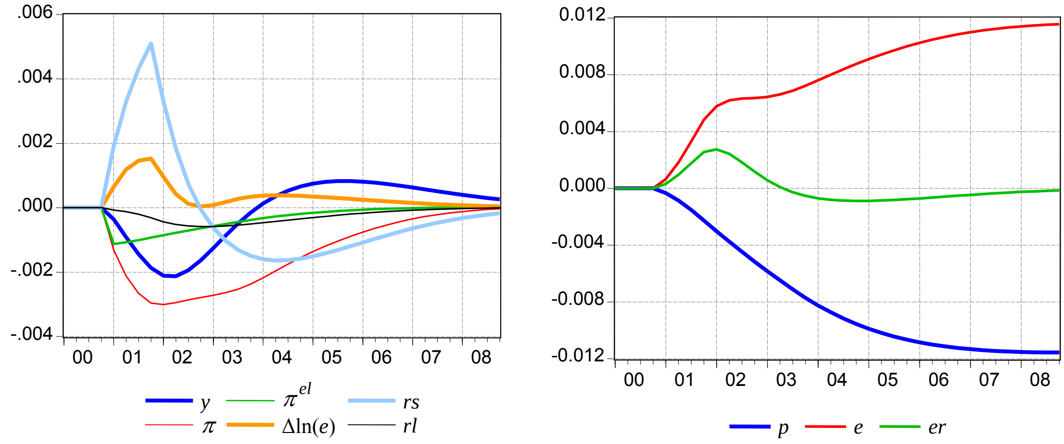
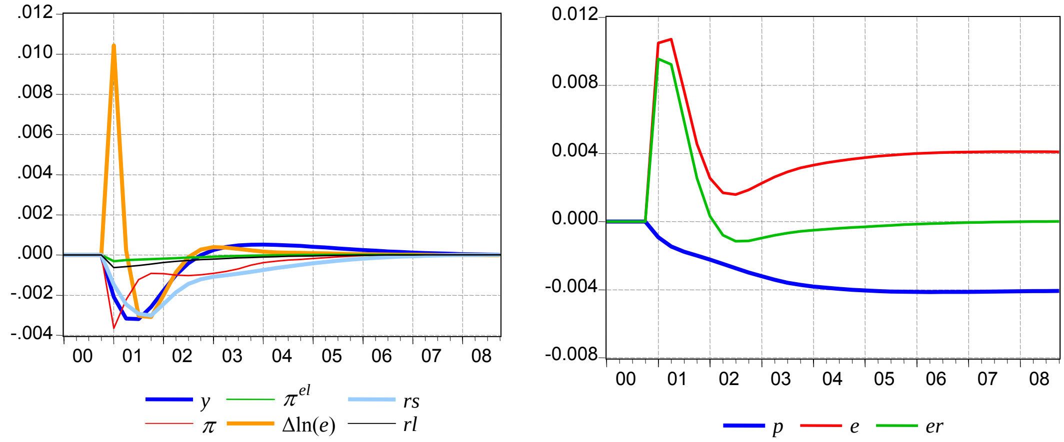
(Figure A5, continued)

c) Money shock (adding four 0.25 PP shocks to the Taylor rule)



d) Exchange rate shock (adding a 1 PP shock to the Exchange rate equation)



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