Structural Vector Autoregressions and the Analysis of Monetary Policy Interventions: The Swiss Case

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1. Introduction

This paper is an empirical analysis of the effects of monetary policy interventions in Switzerland using a structural VAR model. This exercise was motivated by the adoption of a new monetary policy concept by the Swiss National Bank (SNB) at the beginning of the year 2000, which ended a long period of base money targeting. The new framework consists of three elements. First, there is an explicit definition of price stability. Price stability is given if the year to year change in the CPI is less than 2%. Second, a broadly based inflation forecast serves as the main indicator for monetary policy decisions. This forecast is based on different models and indicators including the money aggregate M3. Third, at the operational level, monetary policy is implemented by announcing a 100 basis point target range for the Swiss franc three months London interbank offered rate (3M-Libor).

Since the inflation forecast is the main indicator, this new concept has increased the demand for conditional forecasts of inflation and other key macroeconomic variables given a hypothetical interest rate path. Such forecast simulations should provide important insights for monetary policy decisions. The SNB considers forecasts up to 12 quarters ahead, because the transmission lags of monetary policy are quite long in Switzerland. A persistent overshooting of the inflation forecast

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over the level of 2% under constant interest rates would deliver a signal to tighten monetary policy in the future. However, the SNB’s monetary policy concept is not an explicit inflation targeting strategy, so that there is never a mechanical reaction to the inflation forecast. The inflation forecast is only an indicator but not an intermediate target.

Reduced form VAR models are a standard and efficient tool for unconditional forecasting. However, it is not entirely clear how they can be used for conditional forecasts of monetary policy interventions. Of course, there is the standard approach suggested by Doan, Litterman, and Sims (1984) for calculating VAR-forecasts conditional on fixed paths for a subset of variables. This procedure determines the future reduced form errors of the VAR which guarantee the a priori fixed paths of the variables with a minimal sum of squared errors. Typically, this mechanical approach implies that all error terms are, in general, different from zero during the forecasting period. These reduced form errors, however, represent both non-monetary policy and monetary policy disturbances. None of the reduced form VAR error terms can thus be considered as a control variable of the central bank. A meaningful analysis of monetary policy interventions, therefore, cannot be carried out in a reduced form VAR framework. A structural form VAR is needed, which allows to identify the impact of a monetary policy shock. The size of policy intervention can then be adjusted in the forecasting period subject to the economic conditions. Such an approach will be followed here. A similar approach was proposed by Leeper and Zha (1999), who also offer an interesting view on the appropriateness of the VAR for policy simulations in the light of the Lucas (1976) critique. Briefly, they argue that modest policy interventions, in contrast to fundamental ones, do not change the behavior of private agents and the dynamics of the economy as reflected in the estimated VAR model. Moreover, they make the measure of modest policy interventions operational by proposing an empirical test. In this paper, this approach is modified and applied for the analysis of Swiss monetary policy in the framework of conditional forecasts.

The paper is organised as follows. Section 2 presents the overidentified structural VAR model based on short- and long-run restrictions. The results of the analysis of Swiss monetary policy in this framework are presented in Section 3. Section 4 concludes.
2. A Structural VAR Model for Switzerland

The vector $y_t$ is defined as a vector of changes in four variables

$$y_t' = (\Delta \log p_t, \Delta \log y_t, \Delta \log m_t, \Delta r_t),$$

(1)

where $p$ is the consumer price index, $y$ is GDP in 1990 Swiss francs, $m$ is money measured by the aggregate M1 and $r$ is 3M-Libor for Swiss franc. In order to keep the model as lean as possible the exchange rate is not included in the vector $y$. This may appear inappropriate as Switzerland is clearly a small open economy and the exchange rate is of major importance. However, the transmission of monetary policy via the exchange rate is indirectly represented in the impulse responses of the VAR model. The inclusion of the exchange rate would be a necessity if this variable had influenced monetary policy in a systematic way so that it had to be considered in order to identify a monetary policy shock. Although exchange rate considerations played a major role during some episodes, particularly in 1978/79, this is not true for most of the years since 1973. Moreover, we ought to mention that the usual unit root and cointegration tests confirm the first difference specification adopted.\(^1\)

The fitted VAR($k$) model for vector $y$ corresponds to

$$y_t = \mu + \sum_{i=1}^{k} A_i y_{t-i} + \varepsilon_t,$$

(2)

where $\mu$ is the intercept vector, the $A_i$ are the (reduced form) VAR coefficient matrices, and $k$ is the number of lags included. The vector of error terms is identically and independently distributed with expectation zero and covariance matrix $\Sigma$.

This VAR model is a general reduced form for all variables of interest collected in the vector $y$. Therefore, the error vector $\varepsilon$ usually has no structural interpretation (if the variables are contemporaneously related). In order to identify

\(^1\) Note that we do not select a monetary aggregate which provides a stable long-run money demand function in levels as M3 would. We are only interested in a money stock concept, which provides a lot of information for the identification of a monetary policy shock. The monetary base is not used here as changes in liquidity requirements and the introduction of the Swiss Interbank Clearing System (SIC) in 1988 strongly distorted the demand for base money.
structural shocks and their impulse responses, we have to formulate restrictions on the VAR system. One approach consists of postulating a linear relationship between the reduced form errors and structural shocks

\[ \varepsilon_i = Bu, \]  

(3)

where \( B \) is a (restricted) \( n \times n \) matrix and \( u \) is a vector of white noise structural shocks with identity covariance matrix. Thus, the covariance matrix of the reduced form errors \( \varepsilon \) is given by

\[ \Sigma = B'B. \]  

(4)

This equation should allow us to recover \( n(n+1)/2 \) coefficients of the \( B \) matrix. Thus, we need at least \( n(n-1)/2 \) restrictions in order to identify the \( B \) matrix. Sims (1980) restricted \( B \) to be lower triangular in order to get exact identification. This Choleski decomposition is since then used routinely in VAR analyses. However, such a recursive structure is often not convincing from the viewpoint of economic theory. This critique led to the formulation of structural VARs, which use a non-triangularly restricted matrix \( B \) in line with some economic theory (see, e.g., Bernanke, 1986).

Besides identification of structural shocks by short-run restrictions, the use of so called long-run restrictions represents another approach. This method of structural VAR analysis – introduced by Blanchard and Quah (1989) as well as Shapiro and Watson (1988) – is based on the hypothesis that the long-run effects of certain shocks on specific variables are restricted. This approach is quite attractive for macroeconomic applications on real and nominal variables as economic theory suggests that nominal shocks have no long-run influence on real variables. A first application of the use of both short- and long-run restrictions can be found in Galí (1992).

In order to identify a monetary policy shock in the structural VAR model

\[ A_0 y_i = \mu + \sum_{i=1}^n A_i y_{i-1} + u_i, \]  

(5)

we apply both short- and long-run restrictions. Thereby, we assume that the third element of \( u \) is the monetary policy shock. First, we have two essential short-run restrictions:

\[ a_{0i} = 0, \quad i = 1, 2 \]  

(6)
where $a_{ij}$ is the $ij$ element of $A_0$. This means, of course, that a monetary policy shock has no contemporaneous effect on both consumer prices and GDP. This sluggish reaction of prices and output to monetary policy shocks seems to be a reasonable assumption for quarterly macroeconomic data.

Second, we assume that monetary policy shocks have no long-run effect on GDP and the interest rate. These restrictions can be introduced in the way proposed by Shapiro and Watson (1988):

$$\sum_{i=j}^{0} d_{ij} = 0, \quad i = 2, 4 \quad (7)$$

This means that monetary policy shocks have no long-run effect on both GDP and interest rates. Thus, the dynamic effects are offset in the long run.

With these four restrictions, we are able to identify the form of the impulse responses of the monetary policy shocks. In order to measure the quantitative size of the policy shocks, we have to impose further restrictions. Since we are only interested in the monetary policy shock, the choice of these restrictions depends on computational reasons. The shocks, which are identified by these additional restrictions, do not need to have a structural interpretation. Most important is, however, that the choice of these restrictions does not have an impact on the form of the impulse response functions of the monetary policy shock (see Zha, 1999, Theorem 4). The other restrictions are

$$a_{ij} = 0, \quad i = 1, 2 \quad (8)$$

$$\sum_{i=0}^{j} d_{ij} = 0, \quad i = 2, j = 1, 4 \quad (9)$$

These long-run neutrality restrictions mean that the long-run impulse response matrix $B(1)$ is block triangular. This implies that its inverse, the matrix $A(1)$ is also block diagonal as assumed in Equation (7). Alternatively, the long-run restrictions can be introduced by representing the structural impulse response as function of the reduced form impulse response and the matrix $B$. The restrictions on the long-run impulse responses provide additional restrictions which allow to identify $B$. This approach is, however, only suitable for the case of exact identification. In the case of overidentification, this approach amounts to imposing heavily non-linear restrictions involving powers of the $A$ matrices.
\[ \sum_{j=0}^{k} a_{ij} = 0, \quad i = 4, j = 1 \] 
\[ a_{012} = a_{034} = 0 \] 

We have now eleven restrictions on the contemporaneous and lagged VAR-coefficients. We need at least six restrictions in order to get the necessary condition for identification of the model and have, thus, five overidentifying restrictions.

Given these restrictions we have a system with uncorrected errors and no cross equations restrictions, which is efficiently estimated by (restricted) OLS. The five overidentifying restrictions can conveniently tested by a likelihood ratio test by comparing the restricted likelihood to the one of the exactly identified model without long-run restrictions.

The VAR system can now be transformed or inverted to its impulse response form

\[ y_t = c + \sum_{t=0}^{\infty} \beta_t u_{t-1}, \] 

where the third element of \( u \) is the monetary policy shock. Given our identification scheme an expansive monetary policy is associated with positive values of this shock.

This structural VAR model is estimated with quarterly Swiss data from the first quarter of 1974 to the last quarter of 2002. All variables are seasonally adjusted with the exception of 3M-Libor. The lag length \( k \) is set to five, which is the value selected by the sequential LR test statistic. Before turning to the impulse response estimates, let us briefly mention that the LR test statistic for the null hypothesis of the overidentifying restrictions is 1.94. Under the null hypothesis, this statistic has a chi-square distribution with five degrees of freedom. Therefore, these restrictions cannot be rejected at any reasonable significance level.

Figures 1 and 2 show the impulse responses of the level of the variables to a monetary policy shock. These impulse responses stem from the estimates of the third column of the cumulated \( B \) matrices. In order to get sampling information, we run 1000 bootstrap replications of the OLS residuals corrected for their heteroscedasticity. The figures show the median as well as the 2.5 % and the 97.5 % quantiles of these replications. By and large, these response estimates correspond to the view about the effects of monetary policy held by most macroeconomists in Switzerland: First of all, we have a short-run negative liquidity effect for the
interest rate, which extends over four quarters. The positive reaction of GDP starts after a year, reaches its peak after two years and peters out after three years. With respect to prices, it takes 6 quarters until a major positive effect is felt and 14 quarters are needed for full adjustment of prices. Rising inflationary expectations lead to a temporary increase of the interest rate above its initial level.

It may be mentioned that in our model there is no “liquidity puzzle” (lack of a short-run liquidity effect in interest rates) and “no price puzzle” (negative long-run effect on prices), which are often present in studies for the US and other major industrialised countries. These results are similar to the ones reported in Jordan (1998).

Finally, let us turn to some results concerning the variance decomposition of the variables. Figure 2 represents the variance share of the variables attributed to monetary shocks up to a forecasting horizon of 24 quarters. Monetary shocks make a high contribution to the variance of the money stock and the interest rate in the short run, but in the long run the corresponding variance share sharply decreases. This is a plausible pattern. Somewhat surprisingly, the variance share of the monetary shocks in prices and GDP remains rather low for all forecasting horizon considered. This result may suggest that monetary policy is of no great importance for macroeconomic development. However, such a conclusion would be a misinterpretation of the VAR model. The monetary policy shocks represent only the policy interventions which cannot be explained by the systematic reaction to movements in prices, GDP, money, and interest rate. Such unsystematic policy interventions were plausibly not of greatest importance in a country which aimed at low inflation and price stability during the time span considered.4

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3 The negative one quarter lagged effect of the monetary shock on GDP is not easy to explain. However, zero lies within a 95 percent confidence band for this impulse response coefficient.

4 The related issue of exogenizing monetary policy is discussed in detail by Lee and Zha (1999).
Figure 1:
Impulse Response of Model Variables to a Monetary Policy Shock: SVAR(5), Quarterly Data 1974–2002, Median, 2.5 % and 97.5 % Quantiles of 1000 Bootstrap Runs

Response of CPI to Mon. Policy Shock

Response of 3M-Libor to Mon. Policy Shock
Structural Vector Autoregressions and Monetary Policy Interventions

Response of M1 to Mon. Policy Shock

Response of GDP to Mon. Policy Shock
Figure 2:
Variance Shares of Model Variables Attributed to Monetary Policy Shocks: SVAR(5), Quarterly Data 1974–2002, Median, 2.5 % and 97.5 % Quantiles of 1000 Bootstrap Runs

Variance Share of CPI due to Mon. Policy Shocks

Variance Share of 3M-Libor due to Mon. Policy Shocks
Variance Share of M1 due to Mon. Policy Shocks

Variance Share of GDP due to Mon. Policy Shocks
3. Analysis of Swiss Monetary Policy Using Conditional SVAR Forecasts

In this section, we consider the analysis of Swiss monetary policy using conditional forecasts from the SVAR-model. We determine a sequence of policy shocks which are necessary to fulfil conditions like a given interest rate target path. Before we turn to this exercise in detail, we have to discuss briefly the appropriateness of such an exercise.

First, it might be argued that the change in the strategy of SNB sketched in the introduction invalidates the use of a model fitted to data generated by a different monetary policy procedure. However, we think that this problem is not crucial in the present context. On the one hand, there is no fundamental change in the aim of Swiss monetary policy: price stability is still the goal which has to be achieved and there is now only a more precise definition what is meant by this objective. On the other hand, the change in the operating procedures does not necessarily lead to a break in the time series process of the variables considered in our SVAR model: The two variables used as instruments under the old procedures (bank reserves) and under the new procedure (repo rate), which are probably strongly affected by the change in the operating framework, are not themselves included in our VAR system.

Second, the monetary shocks implied by such a condition like a given interest target path should have no systematic pattern and should not be “large”. Otherwise they would be subject to the Lucas critique, as we may expect a change in the behaviour of private agents in the light of such fundamental changes. In the wording of Leeper and Zha (1999) policy interventions considered in simulations should be “modest”. To this end, we use a statistic similar to the one proposed by Leeper and Zha (1999), namely the mean of all policy shocks over the $K$ forecasting periods.

$$\eta(K,T) = \frac{1}{K} \sum_{t=1}^{K} \eta_{ST + t}$$

(13)

If the simulated policy interventions are not at odds with empirical experience reflected by the estimation sample, we expect this expression to be distributed

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5 These authors used a formulation based on the dynamic effects of the policy shocks to all variables of the system. Of course that is very similar to the formulation used here, but it seems unnecessarily complicated. Furthermore, the chi-squared distribution of the sum of squared shocks under the null could be used.
with expected value zero and variance $1/K$. This hypothesis is easy to test given a sequence of policy shocks obtained by conditioning on a certain policy formulation.

Now let us consider two hypothetical monetary policies over the 12 quarters from the beginning of 2003 to the end of 2005. The first one consists of fixing the interest rate to the very low level valid at the end of 2002, namely 0.5 percent over the subsequent three years. This conditional forecast is of some interest, as it is often used by inflation targeting central banks in order to show the consequences of alternative monetary policy of unchanged nominal interest rates. This strategy can be implemented in the SVAR as follows. First, we calculate an unconditional one-step forecast and then we calculate the next period monetary shock such that the interest rate is equal to its target value:

$$u_{3T+1} = \frac{1}{b_{13}}(E_{T}r_{T+1} - r^*)$$  \hspace{1cm} (14)

This shock is now used to adjust the forecasts of all variables according to the current impulse responses. Given this adjusted $T+1$ forecast, we calculate again an unconditional one-step forecast for period $T+1$ and repeat the adjustment procedure as outlined above. This procedure is followed up to the end of the forecasting horizon $T+K$.

Given the new SNB monetary policy strategy, which is based on inflation forecasts for the subsequent 12 quarters, another conditional forecast also seems to be of some interest. It considers a monetary policy, which reacts symmetrically to positive and negative deviations of the average inflation forecast over the subsequent three years from two percent. This strategy is implemented very similar to the policy of constant nominal interest rates: First we calculate an unconditional one-step forecast and then we calculate the next period monetary shock such that the average expected inflation rate is equal to its target value of two percent

$$u_{3T+1} = \frac{1}{BB_{13}(K)}(E_{T} \log p_{T+K} - (p_T + K\pi^*)),$$  \hspace{1cm} (15)

where $BB$ is the matrix of $K$ period cumulated impulse response. Thus, the element 1,3 of this matrix gives the $K$ period response of the price level to a monetary shock. This shock is now used to adjust the forecasts of all variables according to the current impulse responses. Given this adjusted $T+1$ forecast,
we calculate again an unconditional one-step forecast for period $T+1$ and repeat the adjustment procedure as outlined above. This procedure is followed up to the forecasting horizon $K$.

Figures 3 and 4 show the conditional forecasts for the first quarter of 2003 to the fourth quarter of 2005 obtained by the two approaches outlined above. Again, we run 1000 bootstrap replications of the model estimation and the forecasting simulations and show the median as well as the 2.5% and the 97.5% quantiles of these replications. According to the usual definitions of the relevant variables in Swiss monetary policy discussions, we display the growth rate of consumer prices, GDP and M1 with respect to its four quarters lagged value and the interest rate level. Figure 3 shows that keeping the 3M-Libor constant at the very low level of 0.5 percent (recall that the interest rate was over 3 percent in 2000) does not allow to keep the (median) inflation rate below two percent. This policy is too expansionary and enforces an inflationary momentum over time. With the rising inflation rate, the constant interest rate corresponds to a more and more expansionary monetary policy stance. Of course, given the impulse responses shown in Section 2, the full inflationary consequences of this policy arise outside of our forecasting horizon in the fourth quarter of 2005. The very expansionary monetary policy also leads to a transitory boom in GDP. The question is whether the interest rate can be kept at 0.5 percent for three years by modest policy interventions? Our $\eta$ statistic shows that this is not possible. A value of $\eta = 32.52$ is clearly not in line with a standard normal distribution. Of course, an attempt to fix the interest rate at a historically very low level for several years would lead to an accelerating expansive monetary policy with rising inflation, which is no longer consistent with the estimated model. It is obvious that a long-run fixing of a nominal interest rate level is a policy which is not consistent with the targets of Swiss monetary policy since 1974.

Finally, let us consider the results for the inflation forecast based strategy with a target medium inflation rate of 1%. This policy immediately leads to a restrictive monetary stance with a median interest rate of over 2 percent in 2003. This prevents the strong increase in inflation observed with the constant interest rate policy. Decreasing inflation rates allow a looser stance of monetary policy in 2004, but in 2005 a slight tightening is called for. GDP growth follows this pattern with a considerable lag. Now let us turn to the question whether this policy can be realised by modest shocks. Again, according to our $\eta$ statistic, which has a value of $-0.85$ and is, therefore, in line with the standard normal distribution, this question can be answered by yes. This policy seems to be compatible with the one pursued by the SNB during the sample period used for model estimation.
Figure 3:
Conditional Forecasts of Annual Rate of Changes of Inflation, M1 and GDP Conditional on a 0.5% Interest Rate Path, 2003/I–2005/IV
Median, 2.5% and 97.5% Quantiles of 1000 Bootstrap Runs
Figure 3 (continued):

Forecast of M1 Growth

Forecast of GDP Growth
Figure 4: Conditional Forecasts of Annual Rate of Changes of Inflation, Interest Rate, M1 and GDP Conditional on an Inflation Forecast based Policy, 2003/I–2005/IV
Median, 2.5 % and 97.5 % Quantiles of 1000 Bootstrap Runs
Figure 4 (continued):

Forecast of M1 Growth

Forecast of GDP Growth
4. Conclusions

This paper provides an empirical analysis of the effects of monetary policy interventions based on conditional SVAR forecasts. To this end, we first estimate an over-identified SVAR model with short-run restrictions (no impact effects of monetary policy on prices and GDP) and long-run restrictions (no long-run effects of monetary policy on real variables) which allows us to identify a monetary policy shock with a plausible dynamic response of key macroeconomic variables. There is a four-quarter lasting liquidity effect in interest rates and the influence on GDP reaches its peak after two years and falls to zero after three years. Moreover, it takes 14 quarters until the full effect of a monetary shock is reflected in the price level. Conditional forecasts of this model are then used to evaluate the effect of alternative Swiss monetary policy actions. First, we consider a constant interest rate target of 0.5% percent for the years 2003–2005. The path of policy shocks necessary to keep this interest rate target is not consistent with the SVAR model error structure (i.e., the shocks systematically deviate from zero), and does not allow to keep medium-run inflation below two percent as aimed at by the Swiss National Bank. Alternatively, a monetary policy which is based on a three year average inflation target of one percent is considered. This policy is successful in keeping annual inflation close to one percent for nearly all quarters and does not lead to policy interventions systematically deviating from zero. The implied interest rate path shows an increase to over 2 percent in 2003 and decreases to below 2 percent in 2004 before rising slightly again in 2005. In general, this exercise suggests that SVAR models are a promising tool for the analysis of monetary policy interventions.
5. References


SUMMARY

This paper estimates a structural VAR model for Switzerland consisting of key macroeconomic variables with quarterly data from 1974 to 2002, which allows the identification of a monetary policy shock with plausible impulse response patterns. Conditional forecasts generated by this model are used to analyse monetary policy within the new policy framework of the Swiss National Bank. The generation of these conditional forecasts attempts to take the Lucas critique into account.

ZUSAMMENFASSUNG


RÉSUMÉ

Cet article présente un modèle VAR structurel pour la Suisse avec les principales variables macroéconomiques et l’estime avec des données trimestrielles de 1974 à 2002. Le modèle permet d’identifier un choc de politique monétaire engendrant une réaction plausible des principales variables macroéconomiques. Les prévisions conditionnelles générées par le modèle sont utilisées pour analyser la politique monétaire de la Banque nationale dans le cadre de sa nouvelle stratégie monétaire. La génération de ces prévisions conditionnelles tente de tenir compte de la critique de Lucas.