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Measurement errors in GDP and forward-looking monetary policy: The Swiss case

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Abstract:

This paper analyzes forward-looking rules for Swiss monetary policy in a small structural VAR consisting of four variables. First, the paper looks at the ex ante inflation-output-growth volatility trade-off for a forward-looking policy aiming at a convex combination of a strict inflation and output growth targeting rule implied by this SVAR model. Thereby the paper introduces a new analytical method. Second, the paper considers the effect of measurement errors in GDP on this inflation-output-growth volatility trade-off. Third, the paper works at the impact of changing beliefs about the potential growth rate on the variability of output growth and inflation. Finally the effects of different targets in a forward-looking monetary policy on ex post or unconditional volatility of inflation and output growth is explored by a simulation exercise.

Keywords: Structural VAR, forward-looking monetary policy, efficiency frontier, GDP measurement errors

JEL-Classification: E52, E53

Non Technical Summary

This paper analyses forward looking monetary policy strategies based on medium-term inflation and GDP-growth targets empirically. In particular it considers the volatility trade-off resulting from different weights given to the two targets in a flexible empirical model (a so called structural Vectorautoregression) with and without measurement problems with respect to actual and potential GDP growth. The application of these techniques to Swiss data provide the following four main results: first, without measurement errors caused by data revisions, we obtain the result that reducing the volatility of expected GDP-growth has the consequence of a relatively strong increase in expected inflation volatility. Second, if measurement errors in GDP are taken into account, there is no longer a volatility trade-off over the whole range of weights given to the two targets: increasing the weight of the output growth target from 67 percent to 100 percent increases the volatility of both medium-term expected inflation and GDP-growth. This result is due to the fact that with measurement errors, monetary policy reacts too strongly to noisy data if the weight on output growth targeting becomes too big, as measurement errors have a strong impact on the growth forecast but not on the inflation forecast. The third result shows that this effect of measurement errors is reinforced if policy makers have changing beliefs about potential growth. For a standard deviation of 12.5 basis points per annum for potential growth, we have an increase in the volatility of both expected medium-term inflation and growth if the weight of the output growth target increases from 62 percent to 100 percent. Monetary policy aims at the wrong target and thereby increases the variability of both inflation and output growth. Fourth, these results are strongly enforced when non-equilibrium initial conditions and the consequences of endogenous policy dynamics are taken into account. In fact, in the presence of GDP measurement errors, policy reactions to the inflation and growth consequences of past policy decisions may even destabilize the economy if the weight on the medium-term GDP growth target is high. In general, the paper indicates that under realistic assumptions the central bank induces a higher variability of both output growth and inflation by concentrating too strongly on output growth and strict

medium-term inflation targeting appears as best strategy even when GDP growth variability is of great concern for the central bank.

Nicht technische Zusammenfassung

In dieser Arbeit werden zukunftsgerichtete geldpolitische Strategien, die auf ein mittelfristiges Inflationsziel und BIP-Wachstumsziel ausgerichtet sind, empirisch untersucht. Konkret geht es um den trade-off zwischen der mittelfristigen Inflations- und Wachstumsvolatilität, der sich aus unterschiedlichen Gewichten für das Inflations- und das Wachstumsziel ergibt, mit und ohne Messproblemen beim aktuellen und potentiellen BIP-Wachstum. Die Anwendung der im Rahmen eines flexiblen empirischen Modells (so genannte strukturelle Vektorautoregression) entwickelten Techniken auf Daten für die Schweiz brachte die folgenden vier Hauptergebnisse: Erstens ergibt die Analyse ohne Berücksichtigung der durch Datenrevisionen entstehende Messprobleme für das BIP, dass eine Reduktion der Volatilität des erwarteten mittelfristigen BIP-Wachstums einen relativ grossen Anstieg der erwarteten mittelfristigen Inflationsvolatilität mit sich bringt. Zweitens zeigt sich, dass bei der Berücksichtigung von Messfehlern für das BIP nicht mehr über den ganzen Bereich von Zielgewichten ein trade-off zwischen Inflations- und BIP-Wachstumsvolatilität besteht. Ein Anstieg des Wachstumsgewichts von 67% auf 100% führt zu einer Vergrösserung der Inflations- und Wachstumsvolatilität. Dieses Ergebnis rührt daher, dass die BIP-Messfehler vor allem einen Einfluss auf die Wachstumsprognose und weniger auf die Inflationsprognose haben. Das führt bei einer hohen Gewichtung des Wachstumsziels zu „falschen" Politikreaktionen, die sich letztlich in einer generell höheren Volatilität auswirken. Als drittes Resultat zeigt sich, dass die Auswirkungen von Messfehlern noch durch Ungewissheit der geldpolitischen Behörde bezüglich des potentiellen BIP-Wachstums verschärft werden. So folgt aus einer Standardabweichung der Potentialswachstumsrate von 12.5 Basispunkte des Potentialwachstums um den wahren Wert, dass der Anstieg des Gewichts des Wachstumsziels von 62% auf 100% mit einer Erhöhung der Volatilität des erwarteten mittelfristigen Wachstums und der Inflation verbunden ist. Dieses Resultat ergibt sich aus der Tatsache, dass bei Ungewissheit bezüglich des Potentialwachstums ein falsches GDP-Wachstumsziel anvisiert wird und dadurch generell die Volatilität erhöht wird. Viertens zeigt sich schliesslich, dass die Problematik eines hohen Gewichts des Wachstumsziels weiter verschärft wird, wenn ungleichgewichtige Ausgangsbedingungen und die Dynamik der auf die Folgen vergangener eigener Aktionen reagierende Geldpolitik berücksichtigt werden. Bei einer hohen Gewichtung des Wachstumsziels und Messfehlern bezüglich des GDP-Wachstums kann die Reaktion auf die Inflations- und Wachstumskonsequenzen früherer geldpolitischen Aktionen zu einer Destabilisierung der Volkswirtschaft führen. Generell weisen unsere Resultate darauf hin, dass eine hohe Gewichtung des Wachstumsziels durch die Zentralbank unter realistischen Annahmen zu einer höheren Volatilität der Inflation und des Wachstums in der mittleren Frist führt, und dass damit die Ausrichtung der Geldpolitik auf ein mittelfristiges Inflationsziel empfehlenswert ist.

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1 Introduction

After 25 years of monetary targeting, the Swiss National Bank (SNB) adopted a new monetary policy framework at the end of 1999. Severe shocks to the demand for central bank money, especially for large denominated bank notes and for reserves held by commercial banks at the SNB, rendered it impossible to use the medium-term target path for the seasonally adjusted monetary base as a guideline for monetary decisions. Since also the demand for the broader money aggregate suffered from an insufficient stability, the SNB decided to abandon monetary targeting.

The new framework consists of three elements. The first element is an explicit definition of price stability. The SNB regards price stability as achieved if CPI inflation is below 2 percent. The second element consists of the use of an inflation forecast as the main indicator to guide monetary policy decisions. The third element is a target range for the three-month Swiss franc Libor as an operational target to implement monetary policy. Money aggregates continue to be important, but they are used as information variable rather than as intermediate targets. As in the old concept, maintaining price stability over the medium term remains the main objective of monetary policy also in the new framework.

The SNB strategy shares some elements with inflation targeting. However, it also differs from it in some important respects. The strategy has no inflation target. Rather, the SNB's concept knows a definition of price stability. The SNB has no obligation to keep inflation (or forecasted inflation) under all circumstances and all costs in the range of price stability. Also, the time horizon to bring inflation back in the range of price stability after an inflationary shock is not pre-specified. The SNB analyses each situation individually and decides with regard to the current economic conditions. Contrary to countries pursuing an inflation targeting strategy, the SNB has great independence regarding the exact definition of price stability and the policy reaction if inflation is outside the objective.

In the new framework, the inflation forecast serves as the main indicator for guiding policy decisions. Although there is no mechanical reaction to the inflation forecast and the inflation forecast is not treated as an intermediate target, the discussion about monetary policy is focused on the inflation forecast. The forecast used in the decision-making process is a consensus forecast that is derived from a series of models and indicators. The SNB recently started to publish studies regarding these models. Jordan and Peytrignet (2001) delivered an introduction to the inflation forecast of the SNB and the models used to derive it. Stalder (2001) presented the large traditional structural macro model of the SNB and Jordan, Kugler, Lenz and Savioz (2002) provided an overview over the different VAR approaches used at the SNB.

Since the inflation forecast is crucial for policy decisions, the process of forecasting inflation became very important in the new framework. The forecasts published by the SNB initially semi-annually and from the beginning of 2003 quarterly always assume unchanged nominal interest rates at the current level over the whole forecasting horizon. For internal use and the decision making process, however, there is also a need for different types of forecasts or simulations. Forecasts are for instance also conducted by assuming that the interest rate is adjusted according to an estimated reaction function of the type of a traditional backward-looking Taylor rule.

Forecasts in which the interest rates are adjusted according to a forward-looking rule with an inflation and an output growth target are becoming increasingly important. A crucial question is how much weight should be given to these different targets in order to improve the overall monetary objective of the SNB of maintaining price stability and at the same time to have low variability of inflation and output growth. Using rules with inflation and output growth targets for simulations and forecasting does not imply that the SNB actually pursues an inflation targeting strategy or an output targeting strategy. Rather, the results from these simulations and forecasts are taken into account in the context of the framework explained above and provide some important input to the monetary policy decision making process.

For the purpose of applying forward-looking rules, a small structural VAR consisting of four variables was developed by Kugler and Jordan (2004) and Kugler and Rich (2002). Our paper is an extension of this research and addresses three important issues. First, given the setup of no measurement errors, the paper analyzes the inflation-output-growth volatility trade-off for a forward-looking policy aiming at a convex combination of an inflation and an output growth target implied by this SVAR model. Second, the paper considers the effect of measurement errors in GDP on this inflation-output-growth volatility trade-off. Third, the paper analyzes to what extent changing beliefs about the potential growth rate affect the variability of output and inflation. The paper introduces an analytical method based on the parameters of the impulse response function to solve these questions for the SVAR models, which is a methodological innovation. Fourth, the effects of different targets in a forward-looking monetary policy on ex post or unconditional volatility of inflation and output growth is explored by a simulation exercise.

The brief outline of the aims of the paper at hand clearly indicates that it is related to a growing literature on the effects of uncertainty on potential output and the output gap on the performance of monetary policy rule. Orphanides (2000, 2001) was one of the first who considered this question using real time data for US output gap. He concluded that measurement errors in the output gap were of crucial importance for the over-expansionary US monetary policy in the sixties and seventies and that neglecting such measurement errors leads in general to a too activist policy. However, Svensson and Woodford (2000) argue that this result is mainly caused by the fact that in Orphanides' framework the central bank behaves as if there were no measurement errors and that it disappears when the optimal policy rule is a function of the best estimate of the state variables, in particular of the output gap. This finding is the consequence of the certainty equivalence principle which holds with respect to potential output uncertainty in the usual linear quadratic framework. Nevertheless the presence of uncertainty with respect to potential output results, of course, in welfare losses and has effects on simple Taylor-like rules in standard macroeconomics model (Smets, 2002). Extensions and quantitative illustrations of these results are found in Ehrmann and Smets (2003) who build a small stochastic general equilibrium model with endogenous persistence calibrated to the euro area. Briefly their exercise indicates that the measurement problem leads to substantial welfare losses mainly in the form of high output gap variability. Moreover, simple Taylor rules appear to work well when an optimal output gap estimate is used and potential output uncertainty favors the appointment of a conservative (in the sense of Rogoff (1985)) central banker.

This paper differs from the literature sketched above in the following way. First, we do not consider uncertainty with respect to the output gap or potential output but only with respect to GDP, which is by itself already large as result of strong revisions of the quarterly national accounts. Note also that we do not face the problem of obtaining a best estimate of an unobservable variable such as the output gap since only GDP growth is considered in our model. This approach can be seen as a way to circumvent the problem of measuring the level of potential output as recommended among others by Orphanides (2000). Second, we do not consider an explicit structural model of the economy, but our analysis is based on the impulse response we estimated using a SVAR model. Third, the policy makers do not account for the uncertainty with respect to the real time GDP figures. Thus we proceed on the assumption that the first release quarterly GDP figure is the best estimated data available at the time when the policy decision is taken.

There are three main results of the paper. First, without measurement errors, we obtain a standard convex efficiency frontier for the conditional variance of K period ahead average inflation and growth. Second, if measurement errors in GDP are taken into account, there is no longer a convex efficiency frontier: Decreasing the weight of the output growth target over a certain range, decreases the conditional variance of both inflation and growth. This result is due to the fact that, with measurement errors, monetary policy reacts too strongly to noisy data if the weight on output growth is big. This is because measurement errors have a strong impact on the growth forecast but not on the inflation forecast. The third result shows that the effect of measurement errors is reinforced if policy makers have changing beliefs about potential output growth: With such beliefs, monetary policy becomes a source of volatility itself and thereby increases the variability of both inflation and output growth. Moreover, in the presence of GDP measurement errors, policy reactions to the inflation and growth consequences of past policy decisions may even destabilize the economy if the weight on the medium-term GDP growth target is high. In general, the paper indicates that, under realistic assumptions, the central bank can induce higher output growth and inflation variability by concentrating too much on output growth.

The remainder of the paper is organized as follows. Section 2 sets up the SVAR model for the analysis of Swiss monetary policy. In Section 3, the inflation-growth trade-off is determined in the absence of GDP measurement errors. Measurement errors are taken into account in Section 4 and the impact of changing beliefs about potential output growth is analyzed in Section 5. Section 6 considers the effects of non-equilibrium initial conditions and policy dynamics and Section 7 concludes.

2 A SVAR Analysis of Swiss Monetary Policy

In this section, we give a brief account of the framework used for policy analysis. The VAR model includes a vector of changes in the following four variables:

$$X_t' = (\Delta \log y_t, \Delta r_t, \Delta \log(m_t / p_t), \Delta \log p_t)\,, \tag{1}$$

where y is GDP in 1990 Swiss francs, p denotes the consumer price index, m the money stock M1 and r the quarterly average of the three-month Swiss-franc Libor rate of interest. In order to keep the model as lean as possible, the exchange rate is excluded from vector *X*. This may appear inappropriate as Switzerland is clearly a small open economy, where the exchange rate plays an important role. However, the transmission of monetary policy via the exchange rate is indirectly captured by the impulse responses of the VAR model. Explicit inclusion of the exchange rate would be necessary if this variable had influenced SNB behavior in a systematic way and, therefore, were required to identify a monetary policy shock. Although exchange rate considerations played an important role from time to time, notably in 1978/79, this was not the case for the bulk of the sample period. Note that we do not select a monetary aggregate with a stable long-run money demand function in levels such as M3. We are only interested in a money stock concept providing a lot of information for the identification of a monetary policy shock. The monetary base was not used as the introduction of the electronic Swiss Interbank Clearing System and the relaxation of banks' liquidity requirements in 1978 and 1988, respectively, strongly distorted even the rates of change in this aggregate. However, we should also mention that the result are robust with respect to the in- or exclusion of the money stock series: a three variable VAR without money produces essentially the same shape of the impulse responses to the monetary policy shock as the four variable system. Finally, we ought to mention that the standard unit-root and co-integration tests support the first-difference specification adopted in this paper.[1]

In this paper, long-run neutrality restrictions are used in order to identify structural shocks with variances normalized to 1. Briefly, we have the following interpretation of the four identified shocks. First, there is a supply shock which can either have a permanent or a long-run effect on all four variables considered. Second, we have an IS shock which may have a permanent effect on all variables except for output. Third, there is a money demand shock which affects only the real money stock and prices in the long run. Fourth and most importantly in our framework, we identify a money supply or monetary policy shock which has only a long-run effect on prices (and, of course on the nominal money stock). These six long-run triangularity restrictions lead to an exactly identified model.[2]

All variables included in the model are seasonally adjusted with the exception of the interest rate. The lag length k was set to five quarters, which is the optimal value according to the Akaike criterion. Figure 1 shows the estimates for the cumulated impulse responses of the four variables to all four shocks.[3] In the first column we find the responses of all variables (in the order they appear in the vector x) to the supply shock. Then, we have the responses to the IS-shock, to the money demand shock, and finally in the last column the response to the monetary policy shock which is of most importance in the current context. By and large, the latter response estimates correspond to the views shared by most macroeconomists in Switzerland about the effects of monetary policy. First, there is evidence of a short-run negative liquidity effect on the interest rate extending over two quarters. The positive reaction in real GDP starts weakly and reaches its peak after five quarters and starts to peter out after another year.

1 The results with respect to the interest rate are ambiguous: we cannot reject the unit root hypothesis (ADF test) as well as the stationarity hypothesis (KPSS test). Thus, we proceed on the I(1) hypothesis which is more convenient in our framework for identification of a monetary policy shock. Of course, this implies that the real rate of interest rate is non-stationary what is clearly doubtful in the long-run. However, for the medium-term forecasting horizon considered in this paper this assumption is deemed acceptable.

2 In earlier papers mentioned in the introduction we used an over-identified SVAR model including short-run restrictions. The over-identifying restrictions do not change essentially the results obtained in this paper since that SVAR model produces similar impulse responses for the monetary shock. However, the other shocks are easier to interpret in the current version of the model.

3 No confidence intervals are given in Figure 1. Jordan, Kugler, Lenz and Savioz (2002) show that the effects of the monetary policy shocks are statistically significant.

With respect to prices, it takes six quarters until a major positive effect is felt and 14 quarters are needed for full adjustment of prices. After about the fourth quarter, rising prices and inflation expectations cause the interest rate to overshoot temporarily its long-run equilibrium level. Finally, the real money stock remains constantly over the long-run equilibrium level for a year and decreases to it over the next four quarters. Before turning to the analysis of monetary policy in this SVAR model, let us briefly mention that the impulse responses to the other three shocks are in line with our priors from economic theory. In particular, we find a permanent positive (negative) effect of the supply shock on the production (prices) and the IS shock leads to a hump-shaped transitory response of production extending over 10 quarters which is accompanied by a permanent increase in the price level.

Alternative strategies for Swiss monetary policy can now be analyzed by deriving conditional forecasts from the SVAR model. Specifically, we determine a sequence of policy shocks required to satisfy such conditions as an average inflation target over a two- or three-year period. Before we turn to this exercise in detail, we have to discuss briefly the appropriateness of our approach.

It might be argued that the change in the SNB's monetary regime, as outlined above, invalidates the use of a model fitted to data generated by a different monetary environment. However, we believe that this problem is not of paramount importance in the present context. Price stability remained the ultimate objective of Swiss monetary policy throughout the sample period. Moreover, although the SNB adjusted its operating procedures at the end of 1999, this modification did not cause a break in the time series process of the variables considered in our SVAR model: Bank reserves, used as the main policy instrument before 1999, and the interest rate on repos, the principal new instrument, are not included in our VAR system.

Now consider a monetary policy strategy based on an average inflation forecast for the next K quarters. Take the example of a monetary policy reacting symmetrically to positive and negative deviations from the inflation target π^* measured at a quarterly rate. For such a monetary policy, we get conditional forecasts in the following way: First, we define the expected deviation, as of time t, of the average inflation from its target for horizon K

$$d_p(K,t) = K\pi^* - (E_t \log p_{t+K} - \log p_t) \qquad (2)$$

where $E_t(x_{i,t+K}) = E_T(x_{i,t+K} \mid x_t, x_{t-1}...)$.

Next, we have to determine the sequence of monetary shocks from *t+1* to *t+K* that leads to an expected average inflation which is equal to the target π^*. In Switzerland monetary policy decisions have to be made given final values for CPI inflation and money growth but only a first estimate of GDP growth for the last few quarters. This situation thus differs from the usual assumption in theoretical models that monetary policy can react to current period final values of inflation and output.

There is an infinite number of ways to calculate these shocks. Leeper and Zha (1999) show that policy shocks in VAR-models have to be modest and least disturbing in order not to violate the validity of the simulations. We therefore minimize the sum of the squared shocks subject to the restriction so that the average inflation rate is on target:

$$\begin{aligned} &\sum_{i=1}^{K} u_{4t+i}^2 \to \min \\ &s.t. \quad \sum_{i=1}^{K} AA_{44}(K-i)u_{4t+i} - d_p(K,t) = 0 \end{aligned} \qquad (3)$$

AA (j) is the 4x4 matrix of the impulse response, cumulated over *j* periods. Thus, the element 4,4 of this matrix gives the *j* period cumulated response of inflation to a monetary shock. The solution of this minimization problem is obtained as

$$u_{4t+i} = \frac{AA_{44}(K-i)}{\sum_{j=0}^{K-1} AA_{44}^2(j)} d_p(K,t) = g_{pi} d_p(K,t) \qquad (4)$$

In the remainder of the paper, we call a rule within our SVAR approach based exclusively on an inflation target a *strategy of strict medium-term inflation targeting*.

Of course, we can apply the same approach using the average output growth as a target of monetary policy. Assume that the targeted output growth rate is denoted by γ^*. Again we define first the deviation of the unconditional forecast of the output growth from target *K* periods ahead:

$$d_y(K,t) = K\gamma^* - (E_t \log y_{t+K} - \log y_t) \tag{5}$$

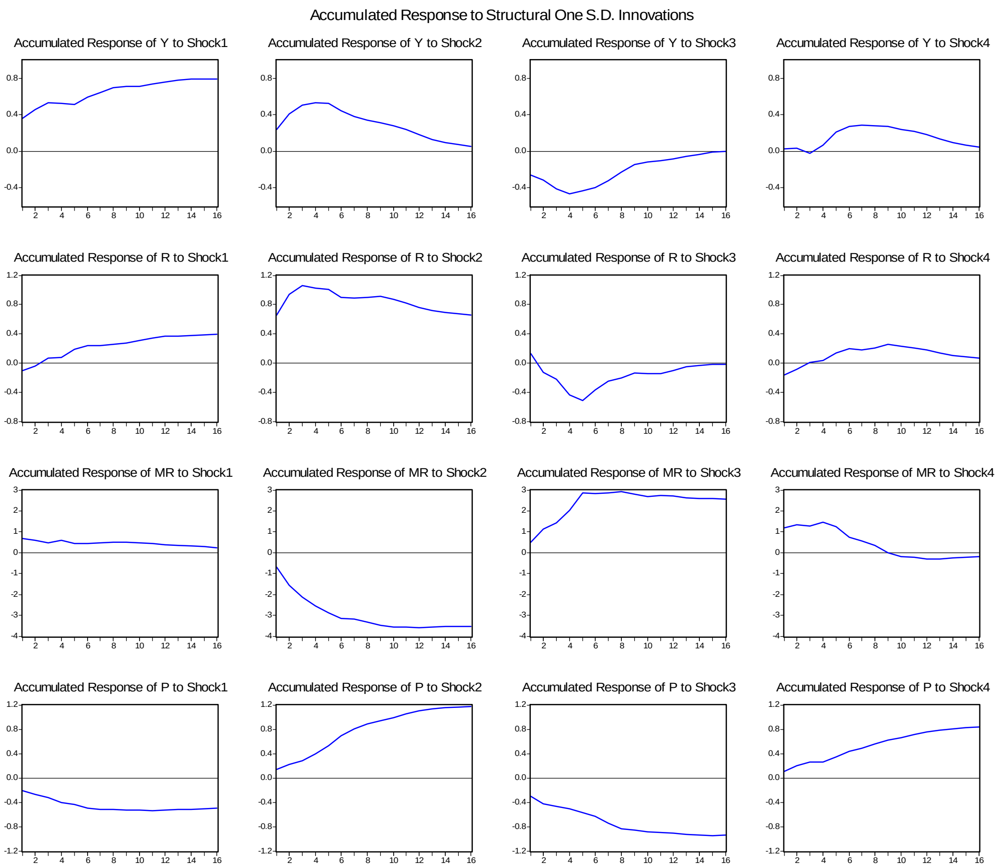
The application of the same procedure as applied for inflation provides us with the following

optimal (in the least squares sense) policy shocks for $t+1$ to $t+K$:

$$u_{4t+i} = \frac{AA_{14}(K-i)}{\sum_{j=0}^{K-1} AA_{14}^2(j)} d_y(K,t) = g_{yi} d_y(K,t) \tag{6}$$

In what follows, we call a rule within our SVAR approach based exclusively on an output growth target a *strategy of strict medium-term output growth targeting*.

Figure 1: Impulse responses of output (*y*), interest rate (*r*), real money stock (*mr*) and prices (*p*) to structural shock, SVAR(5), quarterly data 1974/I-2002/IV



3 The Effect of Structural Shocks on Inflation and Growth Rate Volatility

In this section, we consider the trade-off faced by monetary policy in the framework of our SVAR model. To this end, we consider the variability of inflation and output growth implied by different degrees of medium-term inflation and output growth targeting over the *K*-period horizon. To start with, we define a convex combination of the monetary policy shocks for strict medium-term inflation or output growth targeting derived in the last section:

$$u_{4t+i} = \alpha g_{pi} d_p(K,t) + (1-\alpha) g_{yi} d_y(K,t), \qquad i = 1,\ldots,K \tag{7}$$

This is the situation of a monetary policy board, where the decision is taken by consensus and according to the average preferences of its members. The board members have either the preference for pure inflation targeting or pure output growth targeting in the medium-term. The parameter α thus reflects the fraction of the inflation hawks in the board and $1-\alpha$ is the fraction of the inflation doves. Of course for $\alpha = 1$ we have the case of strict medium-term inflation targeting and for $\alpha = 0$ we follow a strict medium-term output growth targeting. This strategy corresponds to the goal of minimizing the weighted sum of the conditional variability of the expected medium term inflation and output growth rate.

Now let us see to what extent the planned sequence of monetary policy shocks is able to close the deviation of average inflation and output growth rate from their targets. The remaining gap rp_{t+K} (measured as deviation from target) corresponds to the impact of the policy shocks minus the forecasted deviation from target $d_p(K,t)$ induced by the three non-policy shocks at time *t*. These effects can be calculated using the corresponding cumulated impulse responses and equation (7) as well as the formulae for the shocks of the two strict targeting strategies given by equation (4) and (6), respectively:

$$rp_{t+K} = \sum_{i=1}^{K} AA_{44}(K-i)u_{4t+i} - d_p(K,t)$$

$$rp_{t+K} = \sum_{i=1}^{K} \left[\alpha \frac{AA_{44}(K-i)AA_{44}(K-i)}{\sum_{j=0}^{K-1} AA_{44}^2(j)} d_p(K,t) + (1-\alpha)\frac{AA_{44}(K-i)AA_{14}(K-i)}{\sum_{j=0}^{K-1} AA_{14}^2(j)} d_y(K,t) \right] - d_p(K,t)$$

$$rp_{t+K} = \alpha d_p(K,t) + (1-\alpha)G_y d_y(K,t) - d_p(K,t)$$

$$rp_{t+K} = -(1-\alpha)\left[d_p(K,t) - G_y d_y(K,t)\right] \tag{8}$$

$$ry_{t+K} = \sum_{i=1}^{K} AA_{14}(K-i)u_{4T+i} - d_y(K,t)$$

$$ry_{t+K} = \sum_{i=1}^{K} \alpha \left[\frac{AA_{14}(K-i)AA_{44}(K-i)}{\sum_{j=0}^{K-1} AA_{44}^2(j)} d_p(K,t) + (1-\alpha)\frac{AA_{14}(K-i)AA_{14}(K-i)}{\sum_{j=0}^{K-1} AA_{14}^2(j)} d_y(K,t) \right] - d_y(K,t)$$

$$ry_{t+K} = \alpha G_p d_p(K,t) + (1-\alpha)d_y(K,t) - d_y(K,t)$$

$$ry_{t+K} = -\alpha\left[d_y(K,t) - G_p d_p(K,t)\right] \tag{9}$$

For the economic interpretation of the two expression derived above, we briefly consider the (expected) response of the inflation rate to the forecast-oriented monetary policy. If α is equal to one (strict medium-term inflation targeting), we expect to hit the average inflation target exactly. The remaining gap rp_{t+K} (measured as deviation from target) is zero. Otherwise, we expect the medium-term inflation rate to deviate from target. This deviation is determined by the expression in brackets $[d_p(K,t) - G_y d_y(K,t)]$. The first term in brackets is simply the expected unconditional deviation from target for inflation in the medium term. The second term reflects the influence of the reaction of monetary policy to the output growth target. Of course, the latter effect depends on the corresponding deviation from the output target d_y and the co-movement of output and prices in reaction to a monetary policy shock G_y. In fact, G_y can be interpreted as the population regression coefficient of the (*K*-*i*)-period cumulated response of inflation on the (*K*-*i*)-period cumulated response of output growth to a monetary policy shock. Thus, the size of the remaining gap due to not following a strict medium-term inflation targeting rule, depends on the sign and size of G_y as well as on the difference in sign and size between $d_p(K,t)$ and $d_y(K,t)$. The closer G_y is to 1 and the closer $d_p(K,t)$ is to $d_y(K,t)$, the smaller the remaining gap rp_{t+K} will be. In the extreme case of $G_y = 1$ and $d_y(K,t) = d_p(K,t)$, the remaining gap is zero independent of the size of α and thus the trade-off between inflation and output volatility vanishes. Of course, the interpretation for the remaining output growth gap ry_{t+K} corresponds perfectly to that of the inflation gap.

The deviation of the *K*-period ahead log price and log output level from the target path is revised in period *t* according to the shocks hitting the economy. For the sake of simplicity, we assume that we are in equilibrium in time $t-1$ in the sense that we expect to hit both targets in the period *t* to $t+K-1$. However, the non-policy shock of period *t* leads to deviations from the targets, which in turn needs a revision of the monetary policy shock sequence. This leads, of course, to variability of the *K*-period ahead average inflation and output growth rate. In order to calculate this variability, we first note that the deviations of the unconditional forecasts from their targets are given by:

$$d_p(K,t) = -\sum_{l \neq 4} (AA_{4l}(K) - AA_{4l}(0))u_{lt} \tag{10}$$

$$d_y(K,t) = -\sum_{l \neq 4} (AA_{1l}(K) - AA_{1l}(0))u_{lt} \quad (11)$$

where we assume that the policy shock is equal to zero as of time *t*. Note that the structural shocks have an impact effect on prices and output which has to be subtracted as it has no influence on future inflation and growth. Otherwise we have a case of price (output) level targeting as monetary policy has even to compensate the effect of time *t* shocks on the price and output level[4].

Substituting these expressions into the responses of the price and output levels to the policy shocks yields:

$$rp_{t+K} = (1-\alpha)\sum_{l \neq 4} [AA_{4l}(K) - AA_{4l}(0) - G_y(AA_{1l}(K) - AA_{1l}(0))]u_{lt} \quad (12)$$

$$ry_{t+K} = \alpha \sum_{l \neq 4} [AA_{1l}(K) - AA_{1l}(0) - G_p(AA_{4l}(K) - AA_{4l}(0)]u_{lt} \quad (13)$$

The corresponding conditional variances (given information of time *t*) are given by the following expressions:

$$Var_t(rp_{t+K}) = (1-\alpha)^2 \sum_{l \neq 4} [AA_{4l}(K) - AA_{4l}(0) - G_y(AA_{1l}(K) - AA_{1l}(0))]^2 \quad (14)$$

$$Var_t(ry_{t+K}) = \alpha^2 \sum_{l \neq 4} [AA_{1l}(K) - AA_{1l}(0) - G_p(AA_{4l}(K) - AA_{4l}(0))]^2 \quad (15)$$

This implies a linear trade-off in the standard deviations of the output growth and inflation medium-term responses. Of course, this conditional variance is zero for inflation (output growth) when α is 1 (0), otherwise both variances are larger than zero. The reader has to be reminded that these conditional variances are with respect to the *K*-period ahead expected values in *t*. Moreover, they are based on the assumption that we are in long-run equilibrium in period *t*-1. Therefore, they may differ strongly from the unconditional variances of inflation and growth.

[4] In an earlier version of the paper we did not subtract these current effects of the shocks. This means that the average inflation target starts with the time *t-1* equilibrium value of the price level and not its disturbed time *t* value. That approach corresponds therefore to targeting the price level to a deterministic trend and results in higher variances of the average inflation rate. Of course the same reasoning applies to the growth target.

In this context it is important to note that we assume that the central bank uses the correct estimate for potential output growth and thus the deviation from target is zero in the absence of structural shocks. Of course, this is a very strong assumption given the fact that beliefs of policy makers about the potential output growth play an important role in policy decisions. In Section 5, we consider the consequences of such beliefs about potential output growth.

Figure 2 shows the scatter diagram for the 8-period ahead inflation and output growth variance conditional on time *t* information obtained by varying α between 0 and 1. The 8-period time horizon is favorable to output growth targeting because the effect of a monetary shock on output is strong at this horizon whereas only half of the long-run effect on prices has occurred (compare Figure 1). However, it should be mentioned that the results for the 12-quarter horizon for the conduct of monetary policy are qualitatively very similar to those presented below, even though the quantitative effects may be substantial.

We can see from Figure 2 that our SVAR model implies a standard convex efficiency frontier for the conditional variances of inflation and growth. Tolerating a higher variability of output growth allows for a lower variability of inflation and vice versa (trade-off). Thereby, the maximum variability of inflation is clearly higher than the maximum variability of output growth. This result is caused by the higher persistence of the impact of the shocks on inflation than on growth.

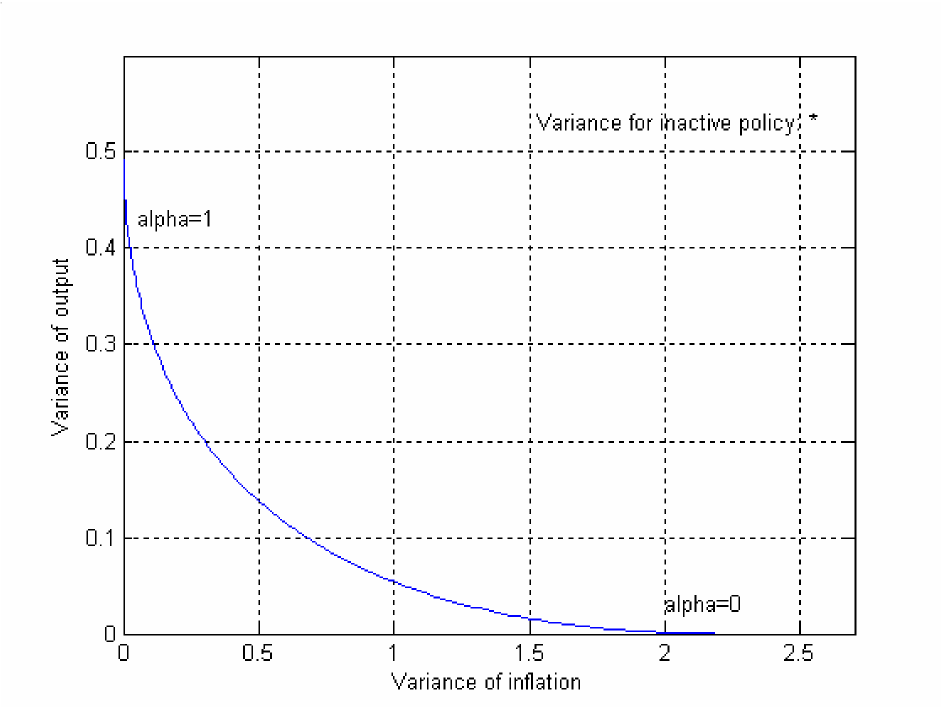
It is interesting to compare the variances of the gaps achieved with an active monetary policy to a situation where monetary policy never reacts to deviations from targets, i.e, the policy shocks are zero. In this case the variances of the gaps would be

$$Var_t(rp_{t+K}) = \sum_{l \neq 4} [AA_{4l}(K) - AA_{4l}(0)]^2 \tag{16}$$

$$Var_t(ry_{t+K}) = \sum_{l \neq 4} [AA_{1l}(K) - AA_{4l}(0)]^2 \tag{17}$$

In Figure 2, we see that this point is far above the efficient frontier which indicates the benefits of an active monetary policy that reacts to new information.

Figure 2: 8-quarters-ahead conditional structural variance of inflation and output growth: structural shocks



4 The Effect of Measurement Errors in GDP on Inflation and Growth Rate Volatility

In this section we analyze the effects of measurement errors on monetary policy induced volatility of inflation and growth. For CPI inflation, measurement errors are not a serious problem given the fact that these data are available on a monthly basis practically without delay and are hardly ever revised. The same applies to money stock data which are only subject to minor revisions. However, measurement or data revision errors are clearly a problem for output as Swiss quarterly real GDP figures of the past year are substantially revised in September when the first release of the annual account for the past year is available. The annual account is itself subject to revisions such that final GDP figures are available with a delay of nearly two years. Moreover, the changes in the base year of the account in 1989 and 1997 lead to additional differences between the final series available today and the real time data of before 1996[5]. The timing of data revisions and the VAR lag length of five imply that real time forecasts in the second and third quarter of each year have to be based entirely on first release GPD figures. In the fourth quarter of each year, lag 4 and 5 values are adjusted to the first release annual account data whereas in the first quarter only for lag 5 adjusted data is available for forecasting.

The first release quarterly GDP figures are based on a regression of annual GDP on annual data of quarterly available production indicators taking into account first order autoregression of the residuals. After the annual data becomes available the difference between the annual GDP figure and the sum of the quarterly first release GDP figures is distributed to the quarterly data taking into account the autocorrelation of the residuals of the regression equation (Chow and Lin, 1971).

Swiss Quarterly GDP data are released regularly with a two months delay since 1980 when for the first time an official historical quarterly account going back to the mid-sixties was published. The difference (expressed in percentage points) between the final 1990 base year figure and the first release is plotted in Figure 3. The GDP measurement error appears as a highly volatile and strongly positively autocorrelated but stationary time series with a mean close to zero. Indeed a standard unit root test clearly rejects the null hypothesis and an AR(1) model with a coefficient close to 0.8 fits the data well. The estimates of the mean, which is not significantly different from zero, and the standard deviation are –0.13 and 1.16, respectively. The standard deviation for the measurement error of the growth rate of GDP, which is relevant in our VAR in first differences, is 0.81. Moreover, there is some slight negative autocorrelation which is not statistically significant and which can be neglected for practical purposes.[6] This measurement error may create substantial problems for forecasting output growth and inflation.

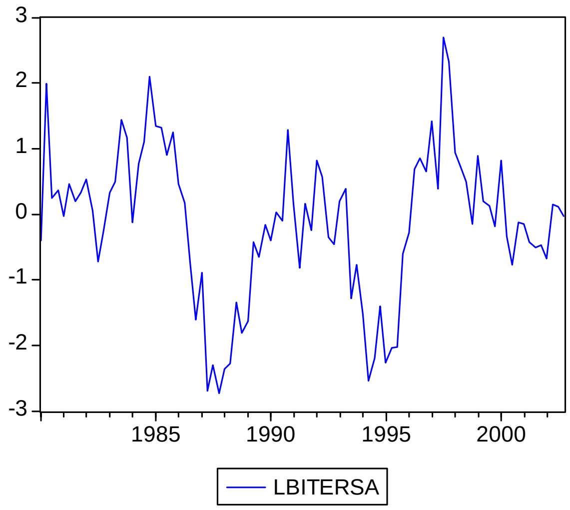
Before turning to the effects of these measurement errors on the volatility trade-off between inflation and GDP growth, we have to briefly discuss the high persistence

[5] These base year changes also reflect conceptual changes in the annual accounts, in particular in 1996. However, we think that these changes also have to be accounted for as they should resulted in better GDP data. The new GDP date was calculated back to 1980 and was used for the estimation of the model.

[6] The first order autocorrelation coefficient is –0.3.

of the measurement errors documented above. At first sight this seems to indicate that the first releases of the GDP figures are sub-optimal estimates. However such a conclusion is not warranted for the following reason: the revision of the quarterly GDP figures within the framework of the Chow and Lin method leads by construction to autoccorrelated revision errors Moreover, a change in the base year when new annual figures for many previous years become available leads to persistent revision errors..

Figure 3: Real time measurement errors of quarterly Swiss GDP 1980-2002 (percentage points)



Before turning to an empirical analysis of the effects of measurement errors using the SVAR framework outlined in the last section we will briefly discuss the issue using a simple theoretical model. Let us consider the standard New Keynesian model discussed in the survey paper of Clarida, Gali and Gertler (1999). It consists of IS-curve, a "new" Phillips curve and a quadratic loss function in inflation π and growth or output gap x of the central bank, which operates by setting the nominal interest rate i

$$\begin{aligned} x_t &= -\varphi(i_t - E_t\pi_{t+1}) + E_t x_{t+1} + g_t \\ \pi_t &= \lambda x_t + \beta E_t \pi_{t+1} + u_t \\ &\frac{1}{2} E_t \sum_{i=0}^{\infty} \beta^i [a x_{t+i}^2 + \pi_{t+i}^2] \end{aligned} \qquad (18)$$

where g and u are zero mean structural shocks which follow an AR(1) process with coefficient μ and ρ, respectively. Of course, this model differs from our SVAR model in many respects and is only used to illustrate the effect of measurement errors in this standard theoretical model. In particular it considers the output gap and not GDP growth and measurement errors arise from uncertainty about potential output in this framework.

In this model optimal monetary policy under discretion is characterized by the following first order condition

$$x_t = -\frac{\lambda}{a}\pi_t \tag{19}$$

implying that demand is contracted by increasing (decreasing) the interest rate when inflation is above (below) target which is supposed to be zero. Now let us assume that the central bank observes *x* only with a zero mean measurement error *e* which follows an AR(1) process with coefficient θ. Therefore, the first order condition fulfilled by the central bank, which neglects this measurement problem, is

$$x_t + e_t = -\frac{\lambda}{a}\pi_t \tag{20}$$

Substituting this disturbed optimality condition in the Phillips curve and applying the method of undetermined coefficient with state variables *u* and *e* (as outlined in the appendix) provides the following solution for inflation and growth:

$$\begin{aligned} \pi_t &= \frac{a}{\lambda^2 + a(1-\beta\rho)}u_t - \frac{\lambda a}{\lambda^2 + a(1-\beta\theta)}e_t \\ x_t &= -\frac{\lambda}{\lambda^2 + a(1-\beta\rho)}u_t - \frac{a(1-\beta\theta)}{\lambda^2 + a(1-\beta\theta)}e_t \end{aligned} \tag{21}$$

This means that a positive measurement error (growth is deemed to be higher by the central bank than it really is) leads to a too restrictive monetary policy resulting in lower growth and lower inflation. Under the (reasonable) assumption that *u* and *e* are not correlated we have the following expressions for the variances of inflation and growth

$$\begin{aligned} \sigma_\pi^2 &= (\frac{a}{\lambda^2 + a(1-\beta\rho)})^2\sigma_u^2 + (\frac{\lambda a}{\lambda^2 + a(1-\beta\theta)})^2\sigma_e^2 \\ \sigma_x^2 &= (\frac{\lambda}{\lambda^2 + a(1-\beta\rho)})^2\sigma_u^2 + (\frac{a(1-\beta\theta)}{\lambda^2 + a(1-\beta\theta)})^2\sigma_e^2 \end{aligned} \tag{22}$$

where σ is the standard deviation of the variable indicated by the lower case letter. When there is no measurement error these expressions imply the standard convex policy efficiency frontier in the variance of growth and inflation which is obtained by varying α from zero to infinity as discussed by Clarida, Gali and Gertler. However, this convexity may be destroyed by the introduction of the GDP measurement error as monetary policy reacts on noisy output data. It can be easily seen from the above expressions that the contribution of the measurement error to the variance of inflation increases with α for both variables. Therefore, increasing a definitely increases the variance of inflation but the effect on the variance of growth is ambiguous: on the one hand the effect of the structural shock and the corresponding variability decreases. On the other hand the effect of the measurement error on output and correspondingly its variability increases. Which of these two effects dominates particularly depends on the relative magnitude of the variance of the structural shock and the measurement error. This means that a measurement error in GDP gives raise to the possibility of an inefficient monetary policy with increasing central bank preferences for output stabilization.

In our empirical model the analysis is much less straightforward as in the simple theoretical model. In particular policy is based on forecasts and not directly on observed values. In this framework we have to analyze the effect of a GDP measurement error on growth and inflation forecasts, which depend on n (equal to the VAR lag length minus one) lagged noisy growth rates in our VAR framework. The easiest way to calculate the effect of the measurement errors on these forecasts is based on the reduced form vector moving average representation of the time $t+i$ (i=1,2..K) value of the vector X defined in equation (1):

$$X_{t+i} = e_{t+i} + C(1)e_{t+i-1} + ... + C(i)e_t + C(i-1)e_{t-1} + ... + C(i-n)e_{t-n} + ... \quad (23)$$

The measurement error in GDP growth (the first element of the vector X) in time t, say v_t, can be interpreted as a change in the first element of reduced form error e in time t and has, therefore, the effect $C_{11}(i)$ on the GDP growth forecast made in t, where $C_{11}(i)$ is the element 1,1 of the reduced form impulse response matrix $C(i)$. Similarly the effect on the inflation forecast is $C_{41}(i)$. If the measurement error is dated time $t-j$

the corresponding effects are $C_{l1}(i-j),\ (l=1,4)$. In our framework we are interested in the cumulated effect of the measurement errors on the inflation and output growth forecast up *K* periods, which are given by

$$de_p(K,t)=\sum_{j=0}^{n}\sum_{i=1}^{k}C_{41}(i-j)\,v_{t-j}, \tag{24}$$

$$de_y\,(K,t)=\left(\sum_{i=1}^{k}C_{11}(i)-1\right)v_t+\sum_{j=1}^{n}\sum_{i=1}^{k}C_{11}(i-j)\,v_{t-j} \tag{25}$$

The current measurement error has a special effect on the forecasted target deviation of output as it effects the period *t* as well as the expected period *t+K* value log output in equation (5). This explains the subtraction of 1 in the first term of the second equation given above.

Let us consider the measurement induced expected deviations from the inflation and growth target. Monetary policy reacts to these deviations according to equation (7) given in Section 3, where *d*-terms are replaced by *de*-terms given in equations (24) and (25):

$$u_{4t+i}=\alpha g_{pi}de_p(K,t)+(1-\alpha)g_{yi}de_y(K,t),\qquad i=1,\ldots,K \tag{26}$$

Therefore, the expected value after the (measurement error) induced policy reaction are given by

$$rep_{t+K}=\sum_{i=1}^{K}AA_{44}(K-i)u_{4t+i} \tag{27}$$

$$rey_{t+K}=\sum_{i=1}^{K}AA_{14}(K-i)u_{4t+i} \tag{28}$$

The evaluation of these expressions - analogous to the derivation of equations (8) and (9) in Section 3 - to the following two equations:

$$rep_{t+K}=\alpha de_p(K,t)+(1-\alpha)G_y de_y(K,t) \tag{29}$$

$$rey_{t+K}=\alpha G_p de_p(K,t)+(1-\alpha)de_y(K,t) \tag{30}$$

Accordingly, we get the following expressions for the conditional (given time t information) variances for these measurement error induced changes:

$$\begin{aligned} & Var(rep_{t+K}) = \\ & \alpha^2 Var(de_p(K,t)) + (1-\alpha)^2 G_y{}^2 Var(de_y(K,t)) \\ & + 2\alpha(1-\alpha) G_y Cov(de_p(K,t), de_y(K,t)) \end{aligned} \tag{31}$$

$$\begin{aligned} & Var(rey_{t+K}) = \\ & \alpha^2 G_p{}^2 Var(de_p(K,t)) + (1-\alpha)^2 Var(de_y(K,t)) \\ & + 2\alpha(1-\alpha) G_p Cov(de_p(K,t), de_y(K,t)) \end{aligned} \tag{32}$$

The covariance matrix of the measurement error induced deviations from target is easily obtained as follows: These two variables can be written as a linear transformation of the n relevant error terms collected in a Vector V, namely DV. The elements of the 2xn matrix D are obtained by the reduced form impulse responses as given above. Thus, the covariance matrix of the two deviations is $DCov(V)D'$ where the covariance matrix of V [$Cov(V)$] is approximately diagonal, given the approximate white noise property of the measurement error. Therefore, the (reduced form) impulse response estimate of our SVAR model and the variance for the measurement error allow the calculation of the variances and the covariance of the two target deviations.

In Figures 4 and 5 the inflation and the output growth variance caused by the measurement error and the induced policy reaction is plotted as function of α for $K = 8$ and n=4, which is the relevant number of lagged measurement errors in our VAR model with lag length 5. In this exercise we assume strictly speaking that we are in the second or third quarter of a year where only first release quarterly GDP figures are available. In the fourth and first quarter we have a slightly different situation. We have first release annual account adjustments for the lags 4 and 5 in the fourth quarter and for lag 5 in the first quarter and correspondingly lower error variances for these lagged values. However this should not make a large difference as the lag 4 and 5 VAR coefficient of GDP growth are relatively small. We can see that the minimum variance in both cases is now obtained with a value of α approximately equal to 0.75. The declining segments of these graphs are brought about by the fact that the reduced form impulse response of the cumulated price level to a reduced form shock in output growth is relatively weak compared to that of output growth itself. The slight increase of the measurement error induced variability is caused by the negative correlation between responses of cumulated growth and inflation. The loss of this "diversification" effect leads to an increase in both variances when the weight of the strict medium-term inflation target gets extreme. However, note that the existence of measurement errors in GDP growth favor a higher weight for the strict medium-term inflation target.

Figure 6 includes 2 scatterplots for different values of α. The first refers to the implied variance of output growth and inflation due to the occurrence of structural shocks and an active monetary policy aiming at compensating the effects of these shocks with different preferences for medium-term inflation and output growth targeting. The second scatterplot adds the variance due to measurement errors. We note that there is no longer a convex efficiency frontier if measurement errors in GDP are taken into account: Decreasing the weight of output growth targeting over some range, i.e., increasing α from 0 to approximately 0.35, decreases the conditional variance of both inflation and growth. Thus, there is no trade-off between smaller output growth variance and higher inflation variance over this range. This result is due to the fact that with measurement errors, monetary policy reacts too much to noisy data if the weight on output growth targeting becomes too big. This occurs because the measurement error has a strong impact on the growth forecast but not on the inflation forecast. However, if $\alpha > 0.75$ this effect is slightly out-weighted by a loss of "diversification" which is brought about by the negative correlation of the measurement error induced responses of medium term inflation and growth.

Figure 4: 8-quarters-ahead conditional variance of inflation caused by measurement errors of GDP

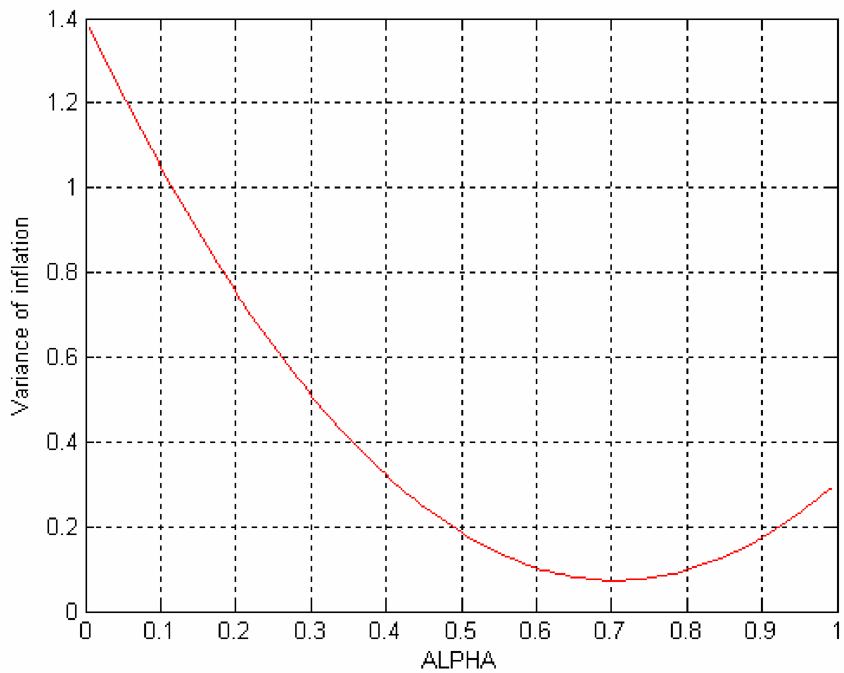


Figure 5: 8-quarters-ahead conditional variance of growth caused by measurement errors of GDP

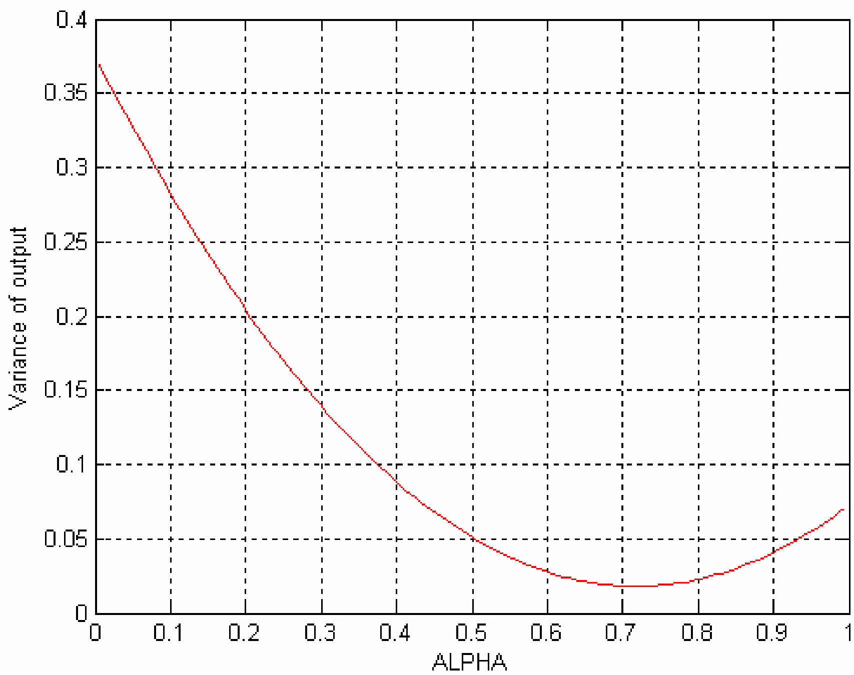
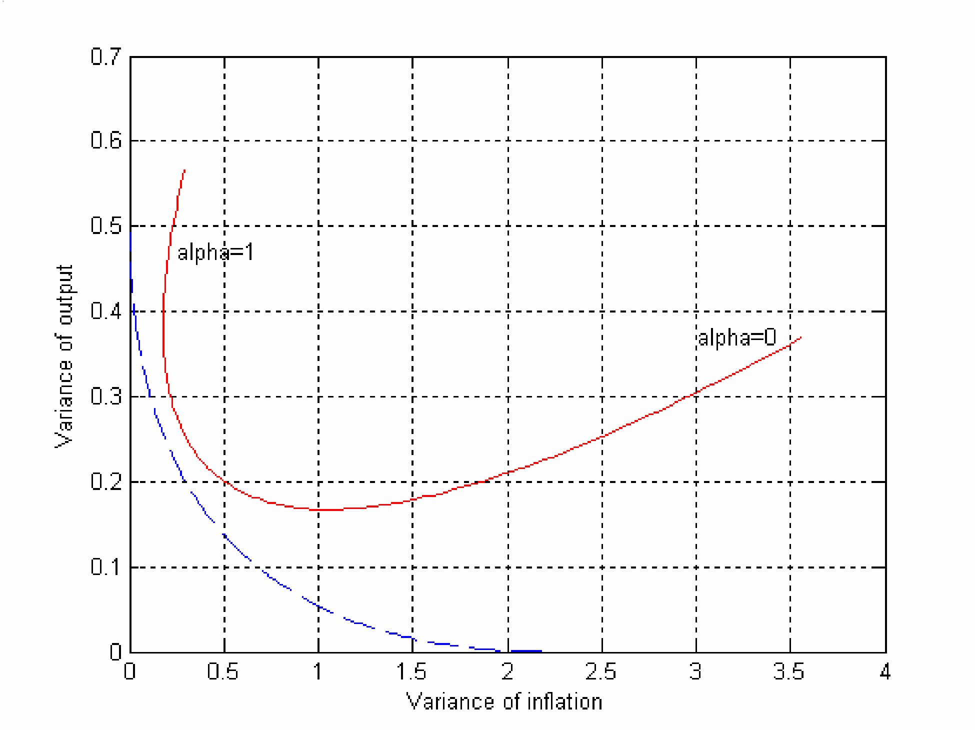


Figure 6: 8-quarters-ahead conditional variance of inflation and output growth: structural shocks as well as structural shocks and measurement errors



5 The Effect of Beliefs about Potential Output Growth Rates

So far we have assumed that the central bank uses the correct estimate of potential output growth for computing the output target $\log y_t + K\gamma^*$. However, policy makers usually have strong private opinions (beliefs) about potential output growth. Their view about the growth rate of potential output often deviates from the one extracted from the model estimates. The policy makers accept the output forecast from the models, but they use their own belief about potential output growth to set the output target. Consequently, the beliefs establish a need for monetary policy actions.

In order to analyze the impact of beliefs on potential output growth on the variance of output growth and inflation, we assume (realistically) that the policy makers form their belief about potential growth rate for each policy decision. Thereby the belief may deviate by η from the true value γ^*. Thus, the belief about the potential growth rate (measured at a quarterly rate) in time *t* is

$$\gamma^*_t = \gamma^* + \eta_t \tag{33}$$

We assume that η is independent from the structural shocks as well as the measurement errors in GDP and is distributed i.i.d. with mean 0 and variance Var(η). Note that in our setup, the central bank does not have a bias for potential output growth and does not generally aim at an unrealistic output growth target. A further question would be to analyze the impact of such a bias, where the central bank tries to push output growth permanently above potential.

The pure effect of these beliefs on the variance of inflation and output growth can be deduced from the result derived in Section 3, by assuming that the structural shocks are zero. The deviation from the output growth target due to the existence of beliefs becomes

$$d\eta_y(K,t) = K\eta_t \tag{34}$$

Note that, in contrast to the measurement errors in past GDP, only the deviation from the output growth target is affected. Again using the result from Section 3, this deviation from target induces a policy reaction yielding

$$r\eta p_{t+k} = (1-\alpha)G_y d\eta_y \tag{35}$$

$$r\eta y_{t+k} = (1-\alpha)d\eta_y \tag{36}$$

The additional variance due to existence of beliefs amounts to

$$Var(r\eta p_{t+k}) = (1-\alpha)^2 G_y^2 K^2 Var(\eta) \tag{37}$$

for inflation and

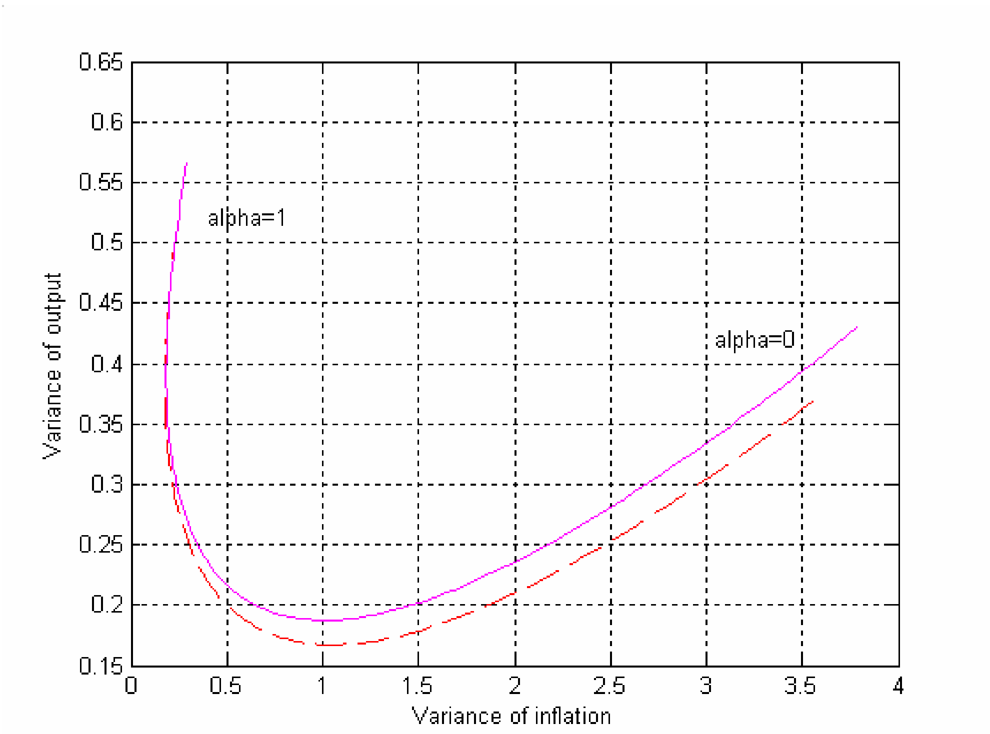
$$Var(r\eta y_{t+k}) = (1-\alpha)^2 K^2 Var(\eta) \tag{38}$$

for output growth.

Figure 7 includes two scatterplots. The first refers to the implied variance of output growth and inflation due to the occurrence of structural shocks and measurement errors. The second scatterplot further adds the variances due the existence of beliefs about potential output growth obtained with a standard deviation of 12.5 basis points per year.

The results show the positively sloping segment of this curve is further increased if volatile beliefs are present and the effect of measurement errors is reinforced: For a standard deviation of 12.5 basis points at an annual rate, we have an increase of both the conditional variance of inflation and output growth if the weight of the output growth target increases from $(1-\alpha)$ = 0.62 to $(1-\alpha)$ = 1. Monetary policy aims at the wrong target and thereby increases the variability of both inflation and output growth. Thus, an output weight above $(1-\alpha)$ = 0.62 is inefficient as it leads to higher inflation and output growth variability.

Figure 7: 8-quarters-ahead conditional structural variance of inflation and output growth: structural shocks and measurement errors as wells as structural shocks, measurement errors and changing beliefs



6 Non-Equilibrium Initial Conditions and Policy Dynamics

So far we have focused our analysis on the effects of time *t* structural shocks on the time *t* expected (conditional) volatility of the *K*-period ahead expected inflation and growth rate given long-run equilibrium in the past. The results obtained under this assumption may differ from those for the unconditional variance of medium-term inflation and growth for two reasons: first, there is no long-run equilibrium in the past and second the realized period $t+K$ outcome depends, of course, also on the shocks and policy decisions in the period $t+1$, $t+2$, …, $t+K$ which depend on the future medium-term inflation and growth forecasts. Moreover, future policy decisions are influenced by current policy decisions which do not only have an effect on average inflation and growth up to $t+K$ but also affect time $t+K+1$, $t+K+2$,…, outcomes.

In order to investigate the effects of different monetary policy strategies on the unconditional variance of medium-term inflation and growth, we use a simulation approach. We take the history of the three structural shocks from 1982 to 2002 and the initial conditions in 1980/81 as given and simulate the development of the four variables of our SVAR model under the assumption that the monetary policy shocks are generated according to Equation (7) for different values of α and using historical averages as inflation and growth targets[7]. The counterfactual series obtained in this way are then used to calculate the variance of medium-term inflation and growth for varying values of α. The generation of the forecasts guiding monetary policy is done firstly by neglecting the GDP revision errors and secondly by using the real time data . The scatter diagrams obtained from these simulations are displayed in Figure 8 and 9, respectively.

Figure 8 differs from Figure 2 in two respects: first, the unconditional variance is substantially (nearly ten times) higher than the time t variance. Second, the efficiency frontier is no longer convex but slightly concave in the unconditional case. This result is brought about by a differing shape of the dependence of the inflation and growth variance on α. The variance of inflation (growth) decreases (increases) with α at a decreasing rate. Therefore, lowering the weight on ouput (inflation) weight in a situation of strict medium-term growth (inflation) targeting leads to a strong (weak) reduction of growth (inflation) variance. The first difference is easy to explain since not only current (time t) shocks are taken into account but also past and future (up to time $t+K$) shocks are accounted for. The non-convex shape of the efficiency frontier is basically explained by the fact that in our framework monetary policy aims at a low ex ante variability of the time t expected medium-term growth and inflation rate and not at the ex post

7 The values are 2.4 and 1.4 percent per annum for inflation and growth, respectively.

variability of these series. The unconditional variance depends in a much more complex way on α than the variance of the time *t* expected variances derived in Section 3. In order to see this complexity it is helpful to consider first the unconditional (no initial equilibrium) deviations from targets which are given by the following equations:

$$d_p(K,t) = -\sum_{j=0}^{\infty}\{(AA_{4l}(K+j) - AA_{4l}(j))u_{4t-j} + \sum_{l=1}^{3} (AA_{4l}(K+j) - AA_{4l}(j))u_{lt-j})\} \quad (39)$$

$$d_y(K,t) = -\sum_{j=0}^{\infty}\{(AA_{1l}(K+j) - AA_{1l}(j))u_{4t-j} + \sum_{l=1}^{3} (AA_{1l}(K+j) - AA_{1l}(j))u_{lt-j})\} \quad (40)$$

The first term in the two equations above gives the effect of past structural and policy shocks on the forecast deviations from target in *t+1*. Under the initial equilibrium assumption these expression reduce to (10) and (11) as only the time *t* structural shocks are different from zero. When these equations are combined with (7) for *i* equal to 1, $u_{4t+1} = \alpha g_{p1} d_p(K,t) + (1-\alpha) g_{y1} d_y(K,t)$, we see that we generate an autoregressive dependence of the policy shock:

$$\begin{aligned} u_{4t+1} = & -\sum_{j=1}^{\infty}\{(\alpha g_{p1}(AA_{4l}(K+j) - AA_{4l}(j)) \\ & + (1-\alpha)g_{y1}(AA_{1l}(K+j) - AA_{1l}(j)))\, u_{4t-j} \\ & + \sum_{l=1}^{3} \alpha g_{p1}\left(AA_{4l}(K+j) - AA_{4l}(j)\right) \\ & + (1-\alpha)g_{y1}\left(AA_{1l}(K+j)\right) - AA_{1l}(j)))\, u_{lt-j}\} \end{aligned} \quad (41)$$

The AR coefficients depend on the K period differences of the cumulated impulse responses of inflation and growth, the weight of strict medium-term inflation targeting and the t+1 policy response under strict medium-term inflation and growth targeting. As the difference of the cumulated inflation impulse response is always positive, we have a negative AR dependence (positive) in the case of strict medium-term inflation (growth) targeting8. To understand this result intuitively, consider a currently expansive monetary policy which leads to an increase in output which is reversed after seven quarters. The reversion of the policy effect calls for an expansionary policy in the future in order to hit the growth target. Therefore, strict medium-term growth targeting can generate self-enforcing policy actions. The same story applies to policy actions to current IS and money demand shocks which have the same hump-shaped cumulated response pattern of GDP growth. This effect plays no role for strict medium-term inflation targeting, as we have a permanent effect of all shocks on the price level which is reached smoothly over time.

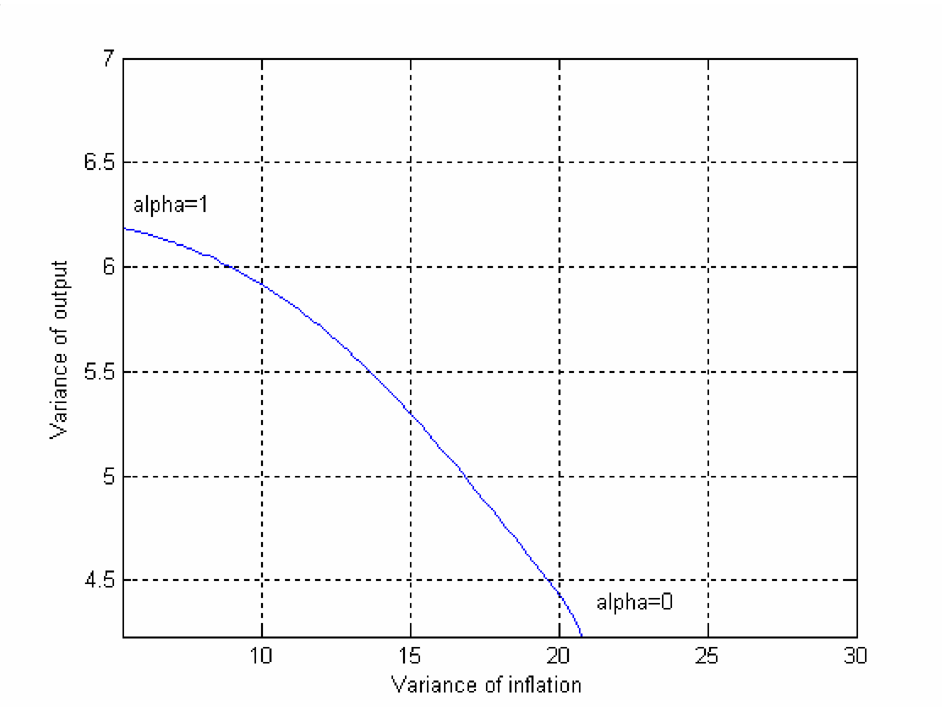
The arguments outlined above indicate that there is a difference between the trade-off in the dynamic context considered in this section and the trade-off in the "static" context of Section 3. In the fully dynamic context, large (small) reductions in inflation variability always have to be paid more or less by large (small) increases in GDP growth variability.

Figure 9 shows that the dynamic effects of the GDP-measurement error lead to an even more pronounced non-standard efficiency frontier. It has an increasing branch for α between 0.45 and 1. This result is brought about by the strong influence of the measurement errors on the GDP forecasts and the implied policy reaction which creates higher inflation and GDP growth variability. This effect out-weighs the small reduction in growth rate variability caused by the decrease of α. For values of α smaller than 0.45, the impact of a lower α (see Figure 8) dominates the impact of measurement errors and thus leads to a strong reduction of growth variability. However, most of this branch is not feasible as the assumption of moderate policy intervention is no longer appropriate. These outcomes require monetary policy shocks that are clearly positive on average and thus invalidate our analysis. In other words, with values of α smaller than 0.3, simulated average inflation rate is between 0.5 to 1.5 percent points per annum above its historical value[9]. Therefore, the consideration of GDP measurement errors in our fully dynamic context sharpens our policy conclusion of Section 4 and 5 strongly in the sense that

[8] Note that the differing sizes of the cumulated impulse responses of inflation and growth are approximately compensated by different value of the g-coefficient which is close to 1/3 and 3/4 for inflation and growth, respectively.

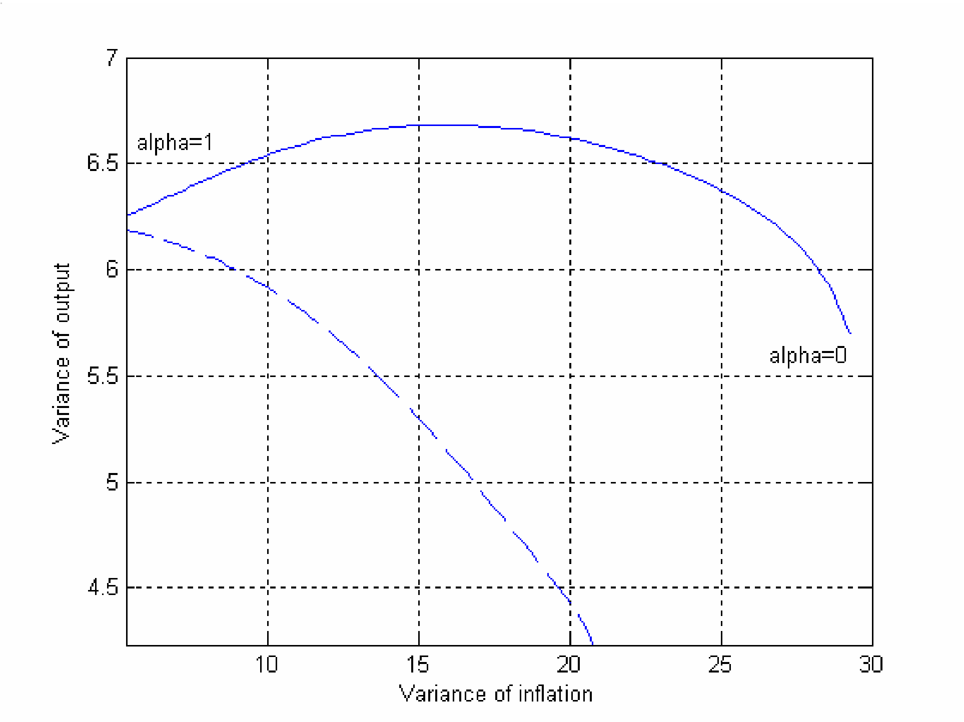
strict-medium term inflation targeting is suggested as a strategy to get inflation and growth variability as low as possible.

Figure 8: 8-quarters-ahead unconditional variance of inflation and output growth: 1982-2002, historical structural shocks and simulated monetary policy with varying α



[9] It should be stressed that for all other simulations we get average monetary policy shocks which are essentially 0 and therefore average simulated inflation rates which are very close to the historical average.

Figure 9: 8-quarters-ahead unconditional variance of inflation and output growth: 1982-2002, historical structural shocks and simulated monetary policy with varying α as well as GDP measurement errors



7 Conclusions

In this paper we analyzed forward-looking rules for Swiss monetary policy in a small structural VAR consisting of four variables. First, given the setup of no measurement errors and no changing beliefs, the paper analyzes the inflation-output-growth volatility trade-off for a forward-looking policy aiming at a convex combination of a strict medium-term inflation and output growth targeting rule implied by this SVAR model. Second, the paper considers the effect of measurement errors in GDP on this inflation-output-growth volatility trade-off. Third, the paper works at the impact of changing beliefs about the potential growth rate on the variability of output growth and inflation. The paper introduces an analytical method based on the parameters of the impulse response function to analyze these questions for the SVAR models. This can be seen as a methodological innovation.

There are three main results of the paper. First, without measurement errors, we obtain a standard convex efficiency frontier for the conditional (time *t*) variance of *K* period ahead expected average inflation and output growth with initial long-run equilibrium conditions. Second, if measurement errors in GDP are taken into account, there is no longer a convex efficiency frontier: Increasing the weight of the output growth target $(1-\alpha)$ from 0.67 to 1 increases the conditional variance of both medium-term expected inflation and growth. This result is due to the fact that with, measurement errors, monetary policy reacts too strongly to noisy data if the weight on output growth targeting becomes too big, as measurement errors have a strong impact on the growth forecast but not on the inflation forecast. However, if $\alpha > 0.75$, this effect is slightly out-weighted by a loss of "diversification" which is brought about by the negative correlation of the policy reaction to measurement error induced responses of medium-term inflation and growth. Therefore, a strict medium-term inflation strategy is inefficient even if the costs of increased volatility of inflation and growth compared to the case $\alpha = 0.75$ are relatively small.

The third result shows that this effect of measurement errors is reinforced if policy makers have changing beliefs about potential growth. For a standard deviation of 12.5 basis points per annum for potential growth, we have an increase of the conditional variance of both inflation and growth if the weight of the output growth target increases $(1-\alpha)$ from 0.62 to 1. Monetary policy aims at the wrong target and thereby increases the variability of both inflation and output growth. These results are strongly enforced when non-equilibrium initial conditions and the consequences of endogenous policy dynamics are taken into account. In fact, in the presence of GDP measurement errors, policy reactions to the inflation and growth consequences of past policy decisions may even destabilize the economy if the weight on the medium-term GDP growth target is high. In general, the paper indicates that under realistic assumptions the central bank induces a higher variability of both output growth and inflation by concentrating too strongly on output growth and strict medium-term inflation targeting appears as best strategy even when GDP growth variability is of great concern for the central bank.

The paper teaches several important policy conclusions. The existence of measurement errors for GDP and changing beliefs about potential growth forcefully underline the limits and the risks of a monetary policy aiming at output stabilization. Even if the central bank only cares about output stabilization, the weight on this target relative to the one of the inflation target should be clearly smaller than 1 or even zero. If the target horizon of central banks becomes shorter, i.e., if the central bank aims at fine-tuning the economy, the risks of pursuing an output growth target strategy become even bigger. Thus, our results confirm the recent findings in Orphanides et al. (2000) and are in fact compatible with the mandates of the European Central Bank, the former Bundesbank and the Swiss National Bank.

The results of the paper can also be linked to the literature on time-inconsistency of monetary policy of the type introduced by Barro and Gordon (1983) and Kydland and Prescott (1977).[10] In a seminal paper Rogoff (1985) showed in this context that delegating monetary policy to a conservative central banker, i.e. a central banker who is relatively more concerned about inflation than the society as a whole, can decrease the variance of both inflation and output growth and thereby improve the welfare of the society. In our model, time-inconsistency is not a problem. However, we can interpret α as the fraction of inflation hawks in a central bank board. Thus, even if the society had strong preference of output stabilization, i.e. if α is 0, it would be an advantage for the society to appoint a conservative board with an α clearly bigger than 0. Such a board may deliver a smaller variability of output growth than a board that reflects exactly the preferences of the public. Consequently, our results support the view that the government should appoint conservative central bankers.

[10] As mentioned in the introduction the same result was obtained by Ehrmann and Smets (2003) in a different modelling framework.

Appendix: Solution of the Theoretical Model of Section 3

Inserting the optimality condition in the Phillips curve results in

$$\pi_t = -\lambda(\frac{\lambda}{a}\pi_t + e_t) + \beta E_t \pi_{t+1} + u_t$$

The model solution is a linear function of the two state variables *u* and *e* with unknown coefficients :

$$\pi_t = \phi_1 u_t + \phi_2 e_t$$

According to the assumed AR(1) structure, the expected value for t+1 is equal to

$$E_t \pi_{t+1} = \phi_1 \rho u_t + \phi_2 \theta e_t$$

Inserting these expressions in the first equation provides

$$(1 + \frac{\lambda^2}{\alpha *})(\phi_1 u_t + \phi_2 e_t) = \beta(\phi_1 \rho u_t + \phi_2 \theta e_t) + u_t - \lambda e_t$$

Equating coefficients on both sides of this equation gives

$$(1 + \frac{\lambda^2}{a})\phi_1 = \beta \phi_1 \rho + 1$$
$$(1 + \frac{\lambda^2}{a})\phi_2 = \beta \phi_2 \theta - \lambda$$

and the unknown coefficients are, therefore, obtained as

$$\phi_1 = \frac{a}{\lambda^2 + a(1 - \beta\rho)}$$
$$\phi_2 = -\frac{\lambda a}{\lambda^2 + a(1 - \beta\theta)}$$

Finally inserting the solution for π in the optimality condition easily results in the solution for *x*.

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