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Abstract

This paper studies regime dependence in macroeconomic dynamics in the U.S. using a threshold vector autoregressive model in which endogenous regime switches are triggered by the inflation rate. The model separates a high from a low inflation regime with both regimes being strongly persistent. Generalized impulse response functions highlight important across-regime differences in the responses of the economy to monetary policy and inflation shocks. Simulating both regimes with individual structural equations interchanged shows a change in inflation dynamics to be the most important source of the transition of the U.S. economy from the high into the low inflation state while the change in the monetary policy reaction functions has only very little effect. Our results indicate that favorable changes in the economic structure and less frequent and smaller shocks are important explanations for the observed decline in U.S. macroeconomic volatility since the mid 1980s.

Keywords: threshold vector autoregression, inflation regimes, Great Moderation

JEL Classification: E32, E58, C32

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1 Introduction

An important strand in the empirical literature on macroeconomic dynamics has used vector autoregressive (VAR) models to study the dynamic interrelations between macroeconomic variables. For example, since the mid 1990s a very succesful research program has investigated the macroeconomic effects of monetary policy. These effects have been identified by estimating the dynamic responses of output, inflation and other variables to "monetary policy shocks".[1] More recently, vector autoregressive models have been used to investigate the causes of the decline in macroeconomic volatility in the U.S. after the mid 1980s (e.g. Gordon, 2005, Stock and Watson, 2003).

This paper uses the standard "monetary policy" VAR model modified by threshold effects to study regime-dependent changes in U.S. Our results contribute to the recent discussion about the causes of the decline in macroeconomic volatility in the U.S. after the mid 1980s. One explanation focuses on beneficial changes in the structure of the U.S. economy making it less vulnerable to shocks. Another explanation is that size and frequency of shocks affecting the U.S. economy declined in this period. These first two explanations are often labelled as "good luck" while the next ones represent "good policy". These argue that the decline in macroeconomic volatility is the effect of improvements in the Fed's monetary policy, represented by an improved monetary policy reaction function and by a reduction in size and frequency of monetary policy shocks, which are the deviations from the monetary policy rule, i.e. the policy residuals. In the first case, the improvement is attributed to the systematic component of monetary policy, in the second case to the unsystematic component.

This paper shows that the time period of this "Great Moderation" coincides with one of the two regimes in the threshold model. Since the multivariate threshold model allows not only for nonlinearities and regime change in the monetary policy reaction function but also in the other economic relationships it enables us to investigate the causes

[1] See Christiano et al. (1999) for a survey.

of the observed improvements in macroeconomic stability by studying differences in the monetary policy reaction functions, in the dynamics of the other macroeconomic variables, and in the structural shocks across regimes. Important information on the relative importance of these elements is gained by studying the regime-transition probabilities. Our results indicate that favorable changes in the economic structure and less frequent and smaller shocks are more important explanations than a significant improvement in systematic monetary policy.

Recent literature has presented evidence on structural change in U.S. macroeconomic dynamics as represented in VARs. For example, Mojon (2008) argues that shifts in the mean of the inflation equation are important for the estimation of the effects of monetary policy shocks in the U.S. Instead of allowing for the change of only one specific parameter our empirical model allows for more general changes in the structural relationships in the economy. Other studies have focused on changes in the monetary policy reaction function of the Federal Reserve within VAR models (e.g. Cogley and Sargent, 2005; Sims and Zha, 2006; Stock and Watson, 2003).

The approaches discussed so far model changes to structural economic relationships and to the monetary policy reaction function as exogenous shifts. Instead of being exogenous these changes might actually be triggered by the state of the economy. In this paper we focus on the level of inflation as the variable which triggers switches between regimes. For example, the relationship between output and inflation (the Philips curve) and the persistence of inflation depend on expected inflation and on the credibility of monetary policy. If high inflation erodes this credibility, inflation dynamics can be affected by changes to the level of inflation. Changes in the monetary policy reaction function can also depend on the level of inflation as the central bank might react differently to shocks depending on the size and direction of the deviation of inflation from its target. For example, Orphanides and Wilcox (2003) and Aksoy et al. (2006) present a model which results in a target zone for inflation. The central bank only responds to shocks which drive the inflation rate outside the target zone. As long as

the inflation rate remains within the target band monetary policy remains passive. This leads to the monetary policy reaction function being different depending on whether the inflation rate is within or outside of the target band. Regime-dependent reactions of monetary policy might also result from credibility concerns. For example, while small deviations of the inflation rate from its target might not cause a loss in public confidence in the central bank's commitment to the inflation target, large deviations might cause the central bank to lose credibility with the public. To avoid this credibility loss, the central bank might respond more aggressively to sizable inflationary excesses than to small ones (e.g. Cukierman, 1992; Cukierman and Meltzer, 1986). Uncertainty about the monetary transmission mechanism might also result in non-linearities in the central bank's reaction function (e.g. Meyer et al., 2001; Swanson, 2006).
Apart from these theoretical concerns an additional advantage of using the inflation rate as threshold variable is that, the period of the "Great Moderation" is associated with a significant decline in the level of inflation. This allows the threshold VAR to endogenously associate one regime with this time period if are indeed significant changes in macroeconomic dynamics can be related to this subsample period.

A straightforward way to model nonlinearities like these empirically is the estimation of a threshold model. Threshold models allow for different regimes, i.e. different sets of model parameters. Which regime applies to a given point in time depends on whether a specific variable, the threshold variable, exceeds a given threshold value. By introducing more than one threshold values the model can accommodate more than two regimes. Univariate threshold autoregressive models have been introduced by Tong (1978) and Tong and Lim (1980).[2] Bunzel and Enders (2010) estimate a nonlinear Taylor rule with a lagged inflation threshold. These models have been extended to a multivariate context by Tsay (1998) and Balke (2000) who tests for regime dependence in macroeconomic dynamics based on a threshold VAR using credit growth as threshold variable. In this paper, we adopt his VAR approach to the study of threshold effects in the standard

[2]See Tong (1990) for an extensive survey.

monetary policy VAR for the U.S.

The paper is structured as follows. Section 2 presents a brief discussion of the threshold VAR model and its estimation. Section 3 contains the estimation results presents evidence on regime-dependent dynamics in the U.S. economy. Section 4 concludes with a discussion of the results.

2 Econometric Methodology

A threshold vector autoregressive (TVAR) model with two regimes can be written as (Balke, 2000)

$$Y_t = \mu^1 + A^1 Y_t + B^1(L) Y_{t-1} + (\mu^2 + A^2 Y_t + B^2(L) Y_{t-1}) I(c_{t-d} > \gamma) + u_t. \tag{1}$$

Y_t is a vector of N endogenous variables. I is an indicator variable that equals 1 when the threshold variable c_{t-d} exceeds a threshold value γ and 0 otherwise. The dynamics of Y_t follow two different regimes dependent on the indicator variable. If $I = 0$ the dynamics of the VAR are given by the vector of constants μ^1, the matrix of contemporaneous interaction coefficients A^1 and the coefficients in the matrix of lag polynomials $B^1(L)$. If $I = 1$ the relevant coefficients are $\mu^1 + \mu^2$, $A^1 + A^2$ and $B^1(L) + B^2(L)$. u_t is a vector of serially and mutually uncorrelated structural innovations. The (diagonal) variance-covariance matrix of these innovations can also be regime dependent Σ_u^i, $i = 1, 2$. By specifying the threshold variable c_t as a function of the variables in Y_t the transition between the two regimes is endogenously determined by the model.

To test for threshold effects the model is estimated by OLS on a grid of possible threshold values chosen to provide for each regime a number of observations equal to the number of coefficients in each equation plus 15% of the overall number of observations.

For each threshold value a Wald statistic is computed and three test statistics for the null hypothesis of no threshold effects are constructed: (sup-Wald) the maximum of the Wald statistic over all possible threshold values, (avg-Wald) the average of the individual Wald statistics, and (exp-Wald) the sum of exponential Wald statistics. The latter two statistics are suggested by Andrews and Ploberger (1994). Testing for threshold effects in (1) is complicated by the fact that the threshold parameter γ is not identified under the null hypothesis of no threshold effects. In order to obtain p-values the empirical distributions of the sup-Wald, avg-Wald and exp-Wald statistics are constructed under the null hypothesis by simulation using the method of Hansen (1996). The estimate of the threshold value is the one minimizing the log determinant of the variance-covariance matrix of the VAR residuals.

We use a standard data set commonly applied to VAR studies of monetary policy in the U.S. It contains quarterly observations on real GDP, the GDP deflator and the monetary aggregate M1. The indicator for monetary policy is the end-of-quarter Federal Funds Rate.[3] Standard VAR studies also include an indicator of commodity prices (e.g. Christiano et al., 1999).[4] We constructed this indicator as the average annualized inflation rates in the price indices for oil (West Texas Intermediate), for agricultural commodities and for metals.[5]

In order to identify the coefficients of the contemporaneous relationships in the A-matrices and the structural shocks we impose a standard recursive causal ordering of the variables of output growth, inflation, commodity price inflation, the Federal Funds

[3]Data was obtained from the FRED II database at the Federal Reserve Bank of St.Louis. http://www.stlouisfed.org/fred2

[4]This variable is included to alleviate the "price puzzle" - an increase in the price level following an exogenous restrictive monetary policy impulse. On explanation for this surprising result is that the central bank reacts to leading information signalling a future increase in inflation. Including a leading indicator of future inflation such as commodity price inflation accounts for endogenous monetary policy reactions to forecasts of higher inflation and thus or reduces the price puzzle (Eichenbaum, 1992). For an in depth discussion, see Hanson (2004)).

[5]This data is from the IMF's International Financial Statistics database.

Rate, and the growth rate of the monetary aggregate (e.g. Christiano et al., 1999).

Including non-stationary data in the VAR might lead to spurios non-linearities (Calza and Sousa, 2005) and might also violate the regularity conditions required to obtain simulated p-values using the Hansen (1996) technique. Hence we set up the VAR in log differences of all variables except for the Federal Funds Rate and include annualized rates of quarter-to-quarter output growth, inflation, commodity price inflation and money growth. The overall estimation period runs from the starting date in Christiano et al. (1999) which is 1965Q3 to 2007Q2.

3 Results

3.1 Threshold Estimates

The threshold VAR (1) was estimated using the lagged inflation rate as the threshold variable $c = \pi$, $d = 1$. Table 1 presents tests for the null hypothesis of no threshold effects in the VAR ($A^2 = B^2(L) = 0, \mu^2 = 0$) based on the complete sample from 1965Q3 to 2007Q2.

Primiceri (2005) and Sims and Zha (2006) argue that most of the time variance in structural VARs is caused by changes in the variance-covariance matrix of the shocks. To account for this, Panels A and B differ in the way the contemporaneous interaction coefficients in A^1 and A^2 and the variance-covariance matrix of the structural VAR residuals are treated. Panel A assumes $A^2 = 0$ and $\Sigma_u^1 = \Sigma_u^2$ by estimating the variance-covariance matrix of the reduced form VAR as being identical in both regimes. Panel B allows for $A^2 \neq 0$ and $\Sigma_u^1 \neq \Sigma_u^2$ by estimating regime-dependent variance-covariance matrices for the reduced form VAR. The results in both panels show strong evidence for the presence of threshold effects and arrive at identical estimates of γ. These estimates are considerably higher than those for the single equation model in Bunzel and Enders (2010). The smallest value for the log determinant of the variance-covariance matrix

Table 1: Tests for threshold VAR
Variables: GDP growth, inflation, com. inflation, Fed Funds Rate, M1 growth

A: No threshold effect in contemporaneous relationships				
threshold variable	Estimated Threshold value	sup-Wald	avg-Wald	exp-Wald
INFLATION	$\gamma = 4.85$	7152.61	1805.84	700.22
Lag=1	LD=9.41	(0.00)	(0.00)	(0.00)

B: Threshold effect in contemporaneous relationships				
threshold variable	Estimated Threshold value	sup-Wald	avg-Wald	exp-Wald
INFLATION	$\gamma = 4.85$	1249.53	299.35	619.47
Lag=1	LD=9.34	(0.00)	(0.00)	(0.00)

NOTES: Sample period is 1965Q3-2007Q2. P-Values in parentheses.

Based on Hansen (1996) with 1000 replications.

of the residuals results for the lagged inflation rate in Panel B. Figure 2 shows a plot of the lagged inflation rate and the estimated threshold value. The high inflation regime prevails from the early 1970s to the mid-1980s. The low inflation regime is associated with the period now termed as the “Great Moderation”. This division of the sample is determined endogenously by the empirical model.

« Insert Figure 1 »

3.2 Generalized impulse responses

In standard VAR models the dynamic adjustment of the variables to structurally identified shocks is studied by using impulse response functions. Impulse response analysis in the TVAR model must account for the possibility of the economy switching between regimes. The construction of the required non-linear or generalized impulse response functions is more complicated than in the conventional linear case since the dynamic behavior of the model depends on both the history of the time series (initial conditions) and the size of the shocks which might affect the shifts between regimes.

The generalized impulse responses of the variables in Y in period k following a shock are defined following Koop et al. (1996) as the differences in the conditional expectations

$$GI_k = E[Y_{t+k}|\Omega_{t-1}, u_t] - E[Y_{t+k}|\Omega_{t-1}]. \tag{2}$$

Ω_{t-1} is the information set at time $t-1$ and u_t is a vector of exogenous shocks which is typically constructed from an identified structural shock to one of the variables in Y.

We construct the non-linear impulse responses using the bootstrap procedure suggested by Balke (2000). For each initial set of observations Ω_{t-1} we draw a random vector of shocks $u_{t+j}, j = 0, \ldots k$ from the regression residuals and simulate the model in order to obtain $E[Y_{t+k}|\Omega_{t-1}]$. Based on the value of the threshold variable in this simulation, the VAR coefficients are allowed to change according to the two regimes. To avoid inducing asymmetries from the draws of u_{t+j} we repeat each simulation with the inverted sequence of $-u_{t+j}$. In order to obtain $E[Y_{t+k}|\Omega_{t-1}, u_t]$ we repeat the procedure using the same random shocks plus an additional perturbation in period t which is constructed from a structural shock to a selected variable using the recursive identification assumption. The difference of these two simulated time-series is the generalized impulse response function. This procedure is repeated seperately for each set of initial observations from each regime using 500 draws of random shock series. Figures 2 - 4 show these impulse responses averaged over all initial observations for each of the two regimes. The procedure used to derive these result differs from the approach in Balke (2000) by the construction of the structural shocks' contemporaneous impact from the regime-dependent variance-covariance matrices of the VAR residuals.

« Insert Figure 2 »

« Insert Figure 3 »

« Insert Figure 4 »

The impulse responses in Figures 2 - 4 are constructed for the specification in Panel B from Table 1 and an inflation threshold of 4.85 percent. The Figures present the dynamic responses of output, inflation and monetary policy dependent on the starting regime to four different shock sizes: a positive two-standard-deviations shock, a positive one-standard deviation shock, a negative one-standard deviation shock, and a negative two-standard-deviations shock. The structural shocks have been scaled to their size in the high inflation regime. In fact, the shocks are significantly larger in the high inflation regime but scaling the shocks to identical size facilitates the comparison of the impulse response functions.[6] The median Federal Funds Rate shock in the high inflation regime is almost three times as large as in the low inflation regime, the inflation shock about 50 percent larger and the output shock is about 25 percent larger. Note however, that these differences might be the result of shifts in the dynamic relationships between the VAR variables (Benati and Surico, 2009).

Asymmetries in the responses to the negative and positive shocks result from differences in the the model switching between the regimes in the adjustment after the different shocks.

In both columns in Figure 2 the responses to the Federal Funds Rate shocks of various sizes in Figure 2 are symmetric. This is a sign for only negligible differences in regime switching being caused by the differently sized shocks. Only after six to seven quarters inflation responds strongly and in the right direction in the high inflation regime but the response is quicker and much more pronounced in the low inflation regime. Output growth shows a quick hump-shaped reaction to the Federal Funds Rate shock but the response is much more pronounced if the economy starts in the high inflation regime. The Federal Funds Rate's reaction to its own shock is more persistent in the low

[6]For similar results, see e.g. Canova and Gambetti (2009), Primiceri (2005), Sims and Zha (2006), and Stock and Watson (2003).

inflation regime.

Little evidence for differences in regime switching after shocks is provided by Figure 4 for the adjustment of the U.S. economy to the shock to GDP growth as most of the impulse responses are symmetric for same sized shocks. Important across starting regime differences are obtained for the inflation rate and for the Federal Funds Rate. Although the overall pattern of the Federal Funds Rate Response is similar in both columns the initial rise in the Federal Funds Rate is temporarily reversed in the fourth quarter after the shock if the economy starts in the high inflation regime. The increase in the inflation rate after a positive shock to output growth is much more persistent if the economy is initially in the low inflation regime.

The results in Figure 3 represent pronounced asymmetries in the dynamic adjustment of output growth to the inflation shock and a stronger reaction of output growth in the high inflation regime. The inflation rate reverts to the baseline path after about three years in the high inflation regime while it remains persistenly above it if the economy started in the low inflation regime, possibly due to the inflation shock enforcing a persistent regime switch.

Figure 5 provides information on the importance of the different structural shocks in causing switches between the two regimes. Each figure in the left column displays the probability of the economy being in the high inflation regime after having started in the high inflation regime and being subject to an exogenous shock. The right column shows the probabilities for the high inflation regime when the economy starts in the low inflation regime. The probabilities are constructed from the simulations underlying the generalized impulse response functions. For each initial set of observations from either regime the VAR is simulated 500 times using randomly drawn residuals and allowing the VAR coefficients to change depending on the lagged inflation rate being above or below the threshold. Figure 9 presents the average frequencies of the economy being in the high inflation regime k periods after being subject to a structural shock to one of the variables. The solid lines show the frequencies which result from simulating the

nonlinear system with just the bootstrapped residuals. The other two lines represent the frequencies derived from combining the bootstrapped residuals with a structural shock of plus or minus two standard deviations to one of the variables in $k = 0$.[7]
The likelihood of the economy switching into the high inflation regime after beginning in the low inflation state is small but non-neglibile even in the absence of structural shocks and rises to about 25% (right column). The strongest effects on these probabilities can be observed for the inflation shock with a large positive shock substantially increasing the likelihood for the high inflation regime. The other shocks have only small effects on the regime probabilities if the economy starts in the low inflation regime.
The probabilities in the left column show the high inflation regime to be highly persistent as well. The probability of the economy being in the high inflation regime declines only slowly to about 50%. As in the case of the low inflation regime these probabilities are noticably affected by inflation shocks but shocks to commodity price inflation and to the Federal Funds Rate have also sizable effects on the regime probabilities. Overall, apart from the inflation shocks, the effects of unexpected disturbances on the persistence of the two regimes are relatively small. Even relatively large shocks have only very limited power to force the economy out of a specific regime or to remain within it.

« Insert Figure 5 »

3.3 Historical decompositions

Balke (2000) proposes a decomposition of the historical time series similar to the standard historical decomposition of a VAR but taking into account the non-linearity implied by the threshold effects. The first element of this decomposition is a a $k+1$ period baseline forecast of Y: $E\left[Y_{t+k}|\Omega_{t-1}\right]$, where the information set Ω_{t-1} consists of all observations on Y from period $t-1$ and before. The contribution of the i-th structural

[7]The shocks again are scaled to the size of the shocks in the high inflation regime.

shock to the forecast error for Y is defined by the change in forecast function(CFF)

$$CFF(\Omega_{t-1}, k, i) = E\left[Y_{t+k}|\Omega_{t-1}, u_t^i, u_{t+1}^i, \ldots, u_{t+k}^i\right] - E\left[Y_{t+k}|\Omega_{t-1}\right], \tag{3}$$

where u_{t+j}^i is the estimate of the i-th structural shock in period $t+j$. Due to the nonlinearity of the TVAR the sum of the individual CFFs does not necessarily add up to the $k+1$-period forecast error for Y. Hence, Balke (2000) defines a remainder term as

$$RM(\Omega_{t-1}, k) = Y_{t+k} - E\left[Y_{t+k}|\Omega_{t-1}\right] - \sum_{i=1}^{N} CFF(\Omega_{t-1}, k, i). \tag{4}$$

Figures 6 - 8 show these decompositions for the ($k = 12$) forecast errors of output growth, inflation, and the Federal Funds Rate. Each graph shows the contributions of three selected structural shocks and of the remainder term to the forecast error of the variable in question. The shading indicates the period in which the high inflation regime prevailed.

All Figures show that the contributions of Federal Funds Rate and inflation shocks were much larger during the high inflation regime. The decline of the contributions of output growth shocks in the low inflation regime is less pronounced than that of the other two shocks. The remainder is mostly relevant for the high inflation regime. The reason for this is that the remainder term is important only if unexpected shocks cause the economy to switch between regimes or prevent a regime switch predicted in the baseline forecast from ocurring. As shown in Figure 5 the economy is likely to remain in the low inflation regime unless being subject to very large shocks. Hence, the remainder is unimportant for the period following the mid-1980s in which the economy settled down in the low inflation regime and the shocks were not large enough to induce regime shifts. In the high inflation regime, the remainder is an important element in explaining the forecast errors of all three variables, particularly for the Federal Funds Rate (Figure 6). Mostly, the remainder has a negative effect on the forecast errors indicating that the non-linear transmission of shocks tended to yield lower realized values of output growth, inflation and the Federal Funds Rate compared to a model with purely linear dynamics.

Also, in the high inflation regime, a sequence of large positive forecast errors for the Federal Funds Rate and the inflation rate can be attributed to structural shocks to inflation. Apart from inflation shocks sizable monetary policy shocks were the second major course of Federal Funds Rate forecast errors (Figure 6). Monetary policy shocks were generally of less importance for inflation forecast errors than inflation shocks except for the early 1970s when Federal Funds Rate shocks pushed the actual inflation rate strongly upward (Figure 7). A substantial part of positive forecast errors in output growth is driven by frequent shocks to output growth itself. Less frequent inflation and Federal Funds Rate shocks are important for output forecast errors as well.

« Insert Figure 6 »

« Insert Figure 7 »

« Insert Figure 8 »

3.4 Counterfactual simulations

Figures 2 - 4 highlighted some important differences between the macroeconomic dynamics in both regimes. An interesting question is what role these different dynamics play in sustaining the economy in one of the two regimes, i.e. in determining the regime probabilities. We investigate the importance of changes in the various structural equations in counterfactual simulations by interchanging one selected structurally identified equation of the VAR between the two regimes.[8]

Figure 9 shows that interchanging the monetary policy reaction function does affect the

[8] Related to this approach are Primiceri (2005) and Sims and Zha (2006) who study the effects of changes in the Federal Reserve's reaction function on causing the "Great Moderation".

probabilities of the economy being in the high inflation regime very little. The Figure combines the results from Figure 5 with simulated frequencies for the VAR with the interchanged Federal Funds Rate equation under the no-structural shock assumption (solid line). The probability of the economy remaining in the high inflation regime does not decline in the left column indicating that the monetary policy reaction function from the low inflation regime does not affect the likelihood of the economy exiting the high inflation state. Since the probability of the inflation regime in the right column increases only slightly the Fed's reaction function from the high inflation regime is not a major source of pushing the economy from the low into the high inflation state.

Figure 10 displays the corresponding results for switching the output growth equation between the two regimes. The results are similar to those in Figure 9 with the change in the output equation causing a slighly stronger rise in the probabilities in the high inflation regime in the left column by about 10 percentage points and slightly lower probabilities in the right column. Finally, Figure 11 shows that changes in inflation dynamics between the two regimes are very important for the regime probabilities. The probabilities of the economy remaining in the high inflation regime (left column) decline substantially by about 25 percentage points. These results suggestare evidence that changes in output and inflation dynamics have been much more imporant than changes in the monetary policy reaction function in forcing the U.S. economy from the high into the low inflation regime.

« Insert Figure 9 »

« Insert Figure 10 »

« Insert Figure 11 »

4 Discussion

The results presented in this paper show strong evidence for important non-linearities and regime-dependence in standard VAR models commonly used in the analysis of U.S. macroeconomic dynamics. The low inflation regime endogenously determined by the threshold model coincides with the period of decreased macroeconomic volatility in the U.S. It has been argued whether the decline in output and inflation volatility was caused by improvements in the Fed's monetary policy ("good policy"), by a reduction in shocks to the U.S. economy ("good luck") (e.g. Gordon, 2005; Primiceri, 2005; Sims and Zha, 2006; Stock and Watson, 2003), or by changes in the structure of the U.S. economy.

In support of the "good luck" we find that the structural shocks to output and inflation were much larger in the high inflation regime than in the low inflation regime. However, the size of the policy shock in the low inflation regime also is only about a third of its size in the other regime. This indicates that in the low inflation regime the Fed followed a more systematic monetary policy and deviated less from its policy reaction function, i.e. monetary policy in the U.S. became more predictable (see also e.g. Canova and Gambetti, 2009). The interpretation of these results is, however, not straightforward as Benati and Surico (2009) argue that such changes might themselves be caused by policy shifts.

We have highlighted some qualitative differences in generalized impulse responses depending on the economy being initially in the high or low inflation regime. These differences result from the interaction of the changes within each individual structural equation with all the other equations in the VAR and this makes it difficult to disentangle the factors driving the differences in the impulse responses. Furthermore, as Benati and Surico (2009) show it is generally difficult for identified VARs to pick up a change in a single structural equation by comparing impulse response functions. Hence, we focused on counterfactual simulations studying how the regime-dependent structural equations in the VAR affected the regime probabilities. Our results show that substantial declines in the probability of the economcy remaining in the high inflation regime were caused by changes in the dynamics of output and inflation but not by the change in the monetary policy reaction function. This indicates that changes to the structural relationships in the U.S. economy have been most important in bringing about the transition from a high to a low inflation regime as argued, for example, by Giannone et al. (2008).

References

Aksoy, Y., Orphanides, A., Small, D., Wieland, V., Wilcox, D., 2006. A quantitative exploration of the opportunistic approach to disinflation. Journal of Monetary Economics 53, 1877-1893.

Andrews, D.W.K., Ploberger, W., 1994. Optimal tests when a nuisance parameter is present only under the alternative. Econometrica 62, 1383-1414.

Balke, N.S., 2000. Credit and economic activity: credit regimes and the nonlinear propagation of shocks. Review of Economics and Statistics 82, 516-536.

Benati, L., Surico, P., 2009. VAR analysis and the Great Moderation. American Economic Review 99, 1636-1652.

Bunzel, H., Enders, W., 2010. The Taylor rule and "opportunistic" monetary policy. CREATES Research Paper No. 2010-4.

Calza, A., Sousa, J., 2006. Output and inflation responses to credit shocks: are there threshold effects in the Euro area?. Studies in Nonlinear Dynamics and Econometrics 10, 1-21.

Canova, F., Gambetti, L. 2009. Structural change in the US economy. Is there a role for monetary policy?. Journal of Economic Dynamics and Control 33, 477-490.

Christiano, L.J., Eichenbaum, M., Evans, C.L., 1999. Monetary policy shocks: what have we learned and to what end?. In: Taylor, J.B., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1A. North-Holland, Amsterdam, pp. 65-148.

Cogley, T., Sargent, T.J., 2005. Drift and volatilities: monetary policies and outcomes in the post WWII US. Review of Economic Dynamics 8, 262-302.

Cukierman, A., 1992. Central Bank Strategy, Credibility, and Independence: Theory and Evidence. Cambridge, The MIT-Press.

Cukierman, A., Meltzer, A.H., 1986. A theory of ambiguity, credibility and inflation under discretion and asymmetric information. Econometrica 54, 1099-1128.

Eichenbaum, M., 1992. Comment on interpreting the macroeconomic time series facts: the effects of monetary policy. European Economic Review 36, 1001-1011.

Giannone, D., Lenza, M., Reichlin, L., 2008. Explaining the Great Moderation: it is not the shocks. European Economic Review 6, 621-633.

Gordon, R.J., 2005. What caused the decline in U.S. business cycle volatility. NBER Working Paper No. 11777.

Hansen, B.E., 1986. Inference when a nuisance parameter is not identified under the null hypothesis. Econometrica 64, 413-430.

Hanson, M.S., 2004. The "price puzzle" reconsidered. Journal of Monetary Economics 51, 1384-1413.

Koop, G.M., Pesaran, H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. Journal of Econometrics 74, 119-148.

Meyer, L.H., Swanson, E.T., Wieland, V., 2001. NAIRU uncertainty and non-linear policy rules. American Economic Review 91, 226-231.

Mojon, B., 2008. When did unsystematic monetary policy have an effect on inflation?. European Economic Review 52, 487-497.

Orphanides, A., Wilcox, D., 2002, The opportunistic approach to disinflation. International Finance 5, 47-71.

Primiceri, G., 2005. Time varying structural vector autoregressions and monetary policy. Review of Economic Studies 72, 831-852.

Sims, C.A., Zha, T., 2006. Were there regime switches in US monetary policy?. American Economic Review 96, 54-81.

Stock, J.H., Watson, M.W., 2003. Has the business cycle changed and why?. In: Gertler, M., Rogoff, K.R. (Eds.), NBER Macroeconomics Annual 2002. The MIT-Press, Cambridge, pp. 159-218.

Swanson, E.T., 2006. Optimal non-Linear policy: signal extraction with a non-normal prior. Journal of Economic Dynamics and Control 30, 185-203.

Tong, H., 1978. On a threshold model. In: Chen, C.H. (Ed.), Pattern Recognition and Signal Processing. Sijthoff & Noordhoff, Amsterdam, pp. 101-141.

Tong, H., 1990. Nonlinear Time Series: A Dynamical System Approach. Oxford University Press, Oxford.

Tong, H., Lim, K.S., 1980. Threshold autoregressions, limit cycles, and data. Journal of the Royal Statistical Society B 42, 245-292.

Tsay, R.S., 1998. Testing and modeling multivariate threshold models. Journal of the American Statistical Association 93, 1188-1198.

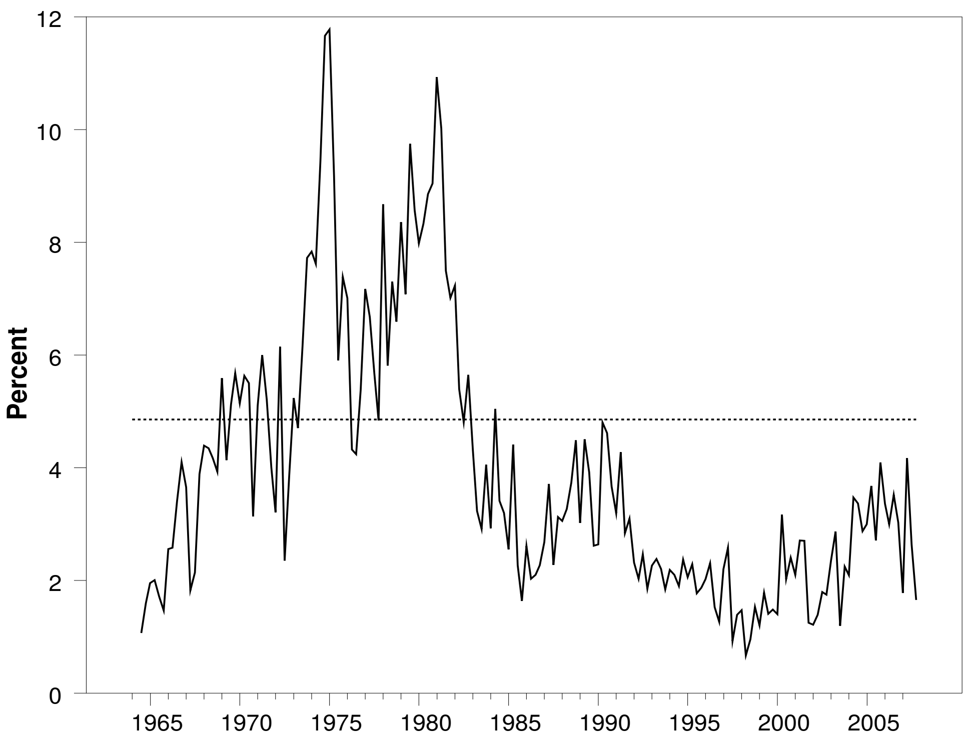

Figure 1: Lagged inflation and estimated inflation threshold

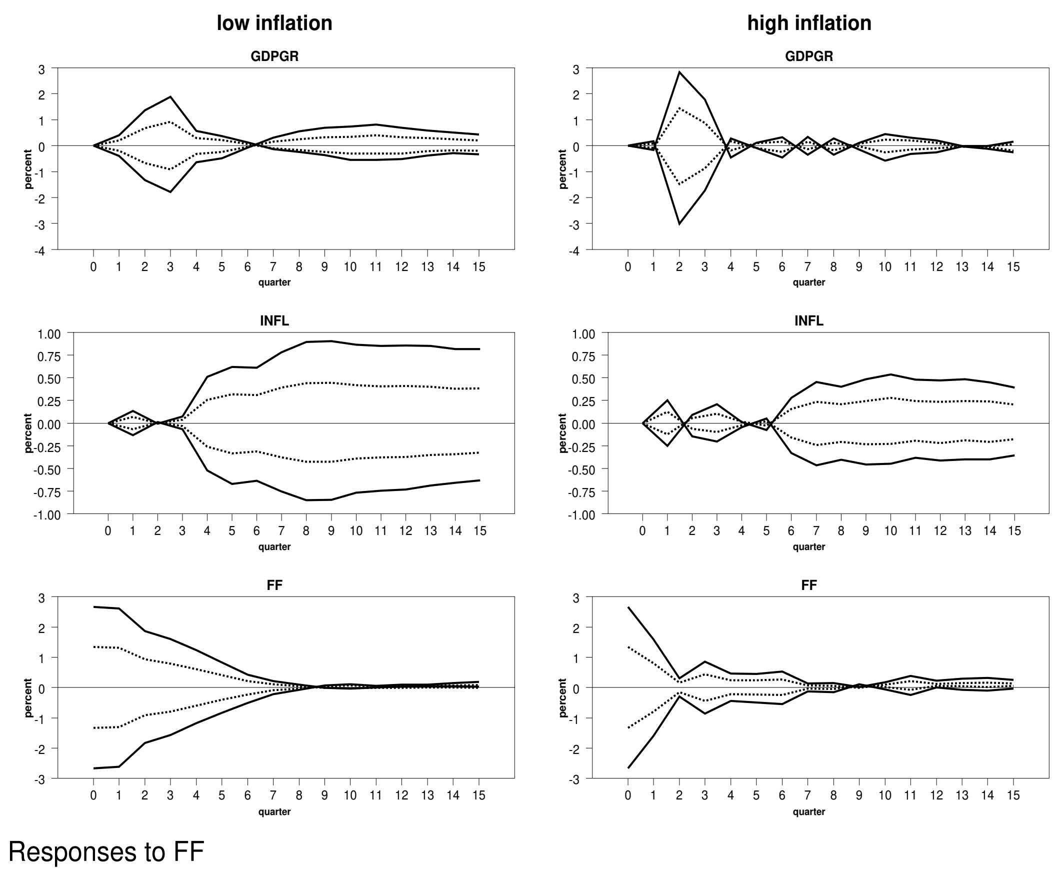

Figure 2: Generalized impulse responses to monetary policy conditional on initial regime. (Shocks: ± 2SD (solid), ± 1SD (dotted))

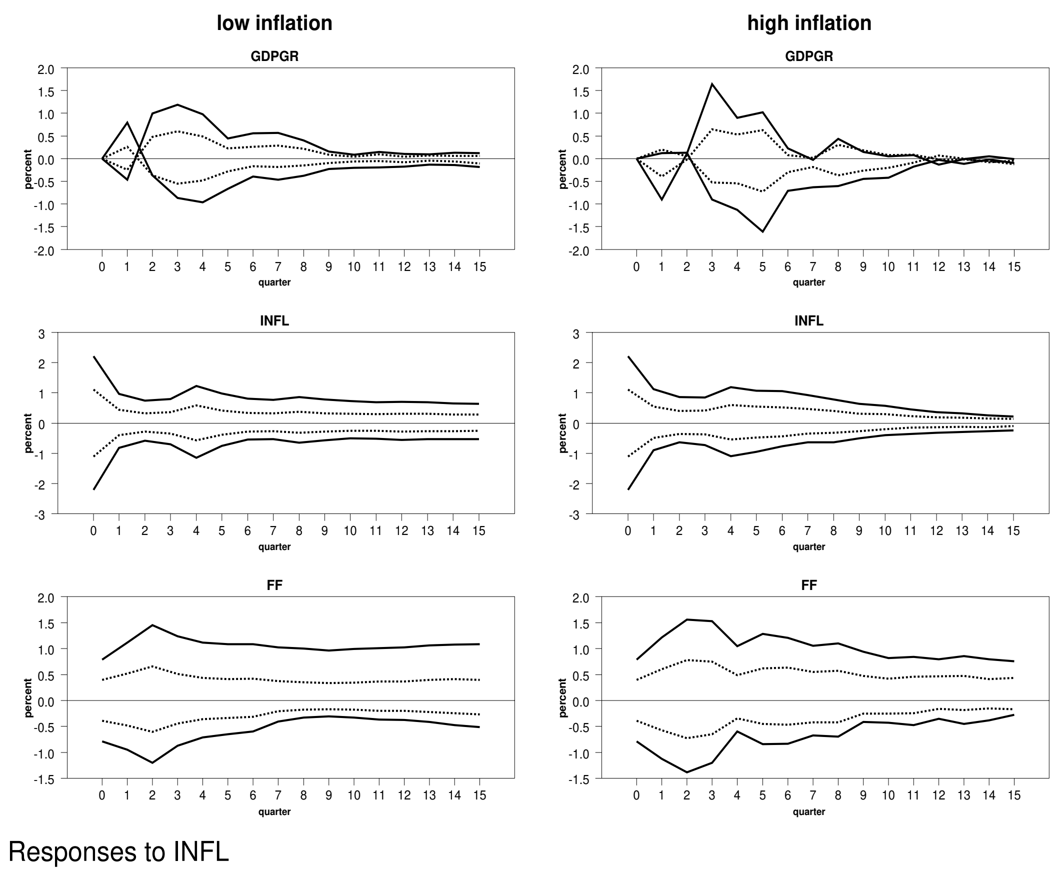

Figure 3: Generalized impulse responses to inflation conditional on initial regime. (Shocks: $\pm$ 2SD (solid), $\pm$ 1SD (dotted))

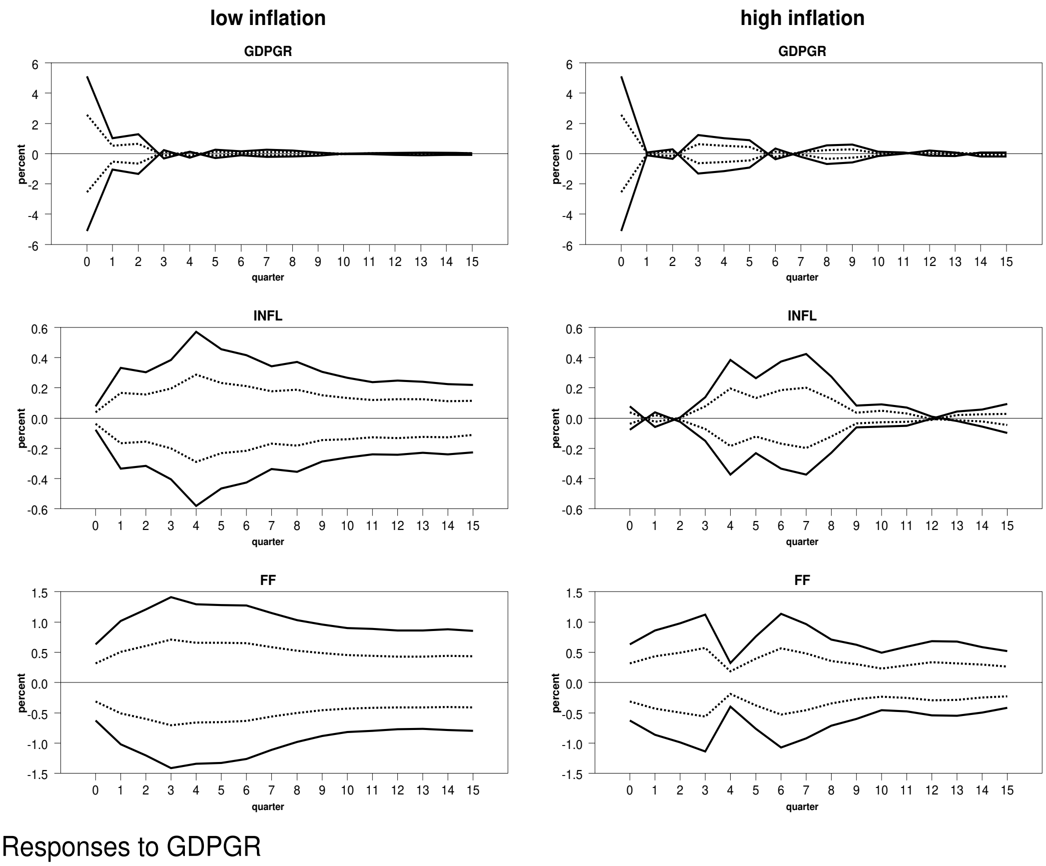

Figure 4: Generalized impulse responses to output growth conditional on initial regime. (Shocks: ± 2SD (solid), ± 1SD (dotted))

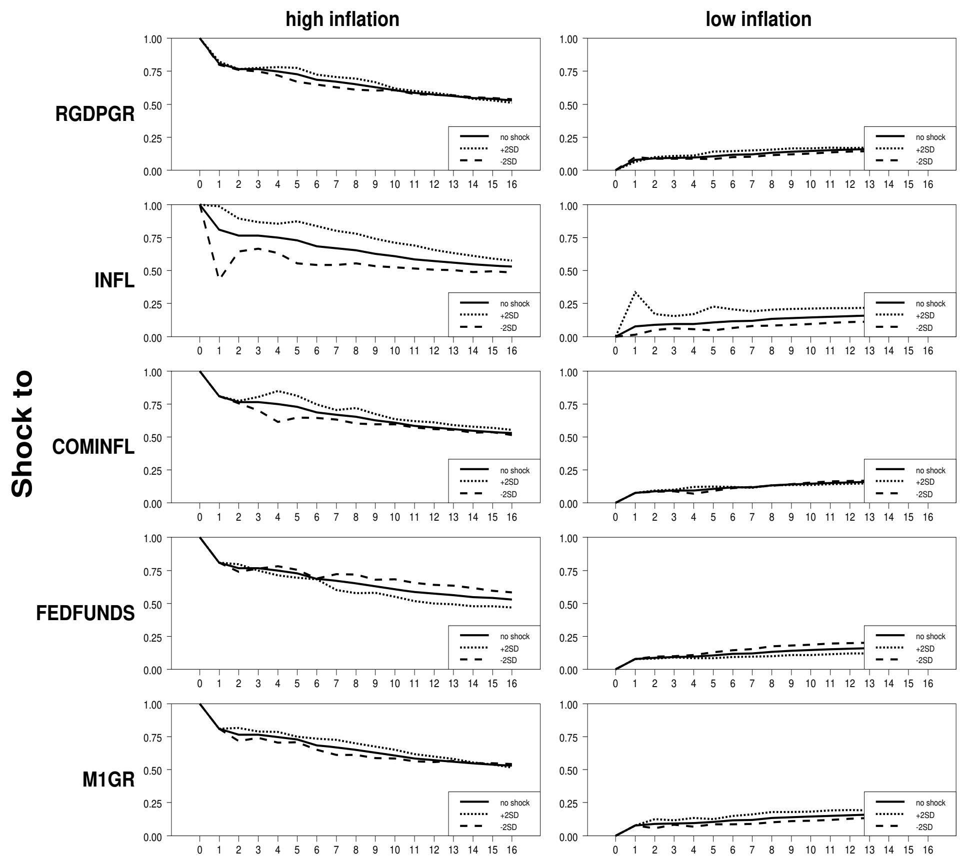

Figure 5: Probability of high inflation regime conditional on starting regime.

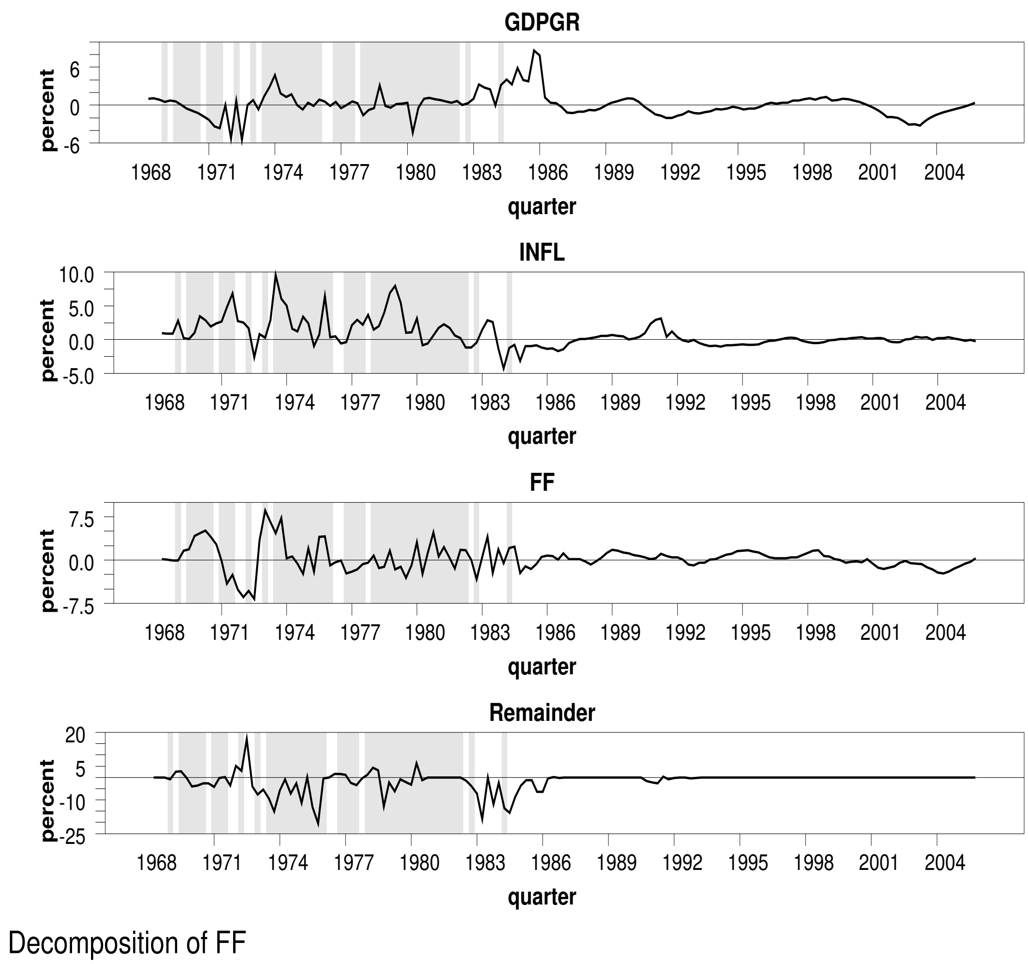

Figure 6: Forecast error in Federal Funds Rate attributed to shocks during previous twelve quarters.

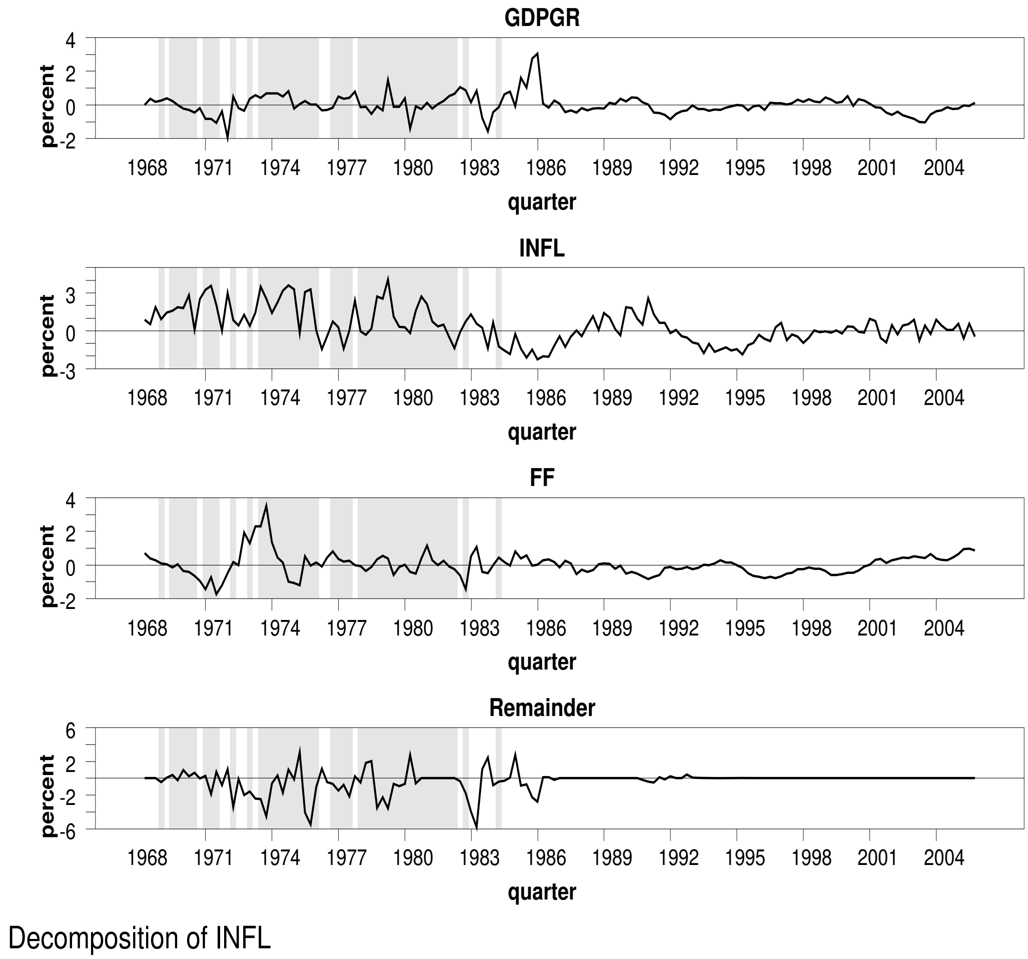

Figure 7: Forecast error in inflation attributed to shocks during previous twelve quarters.

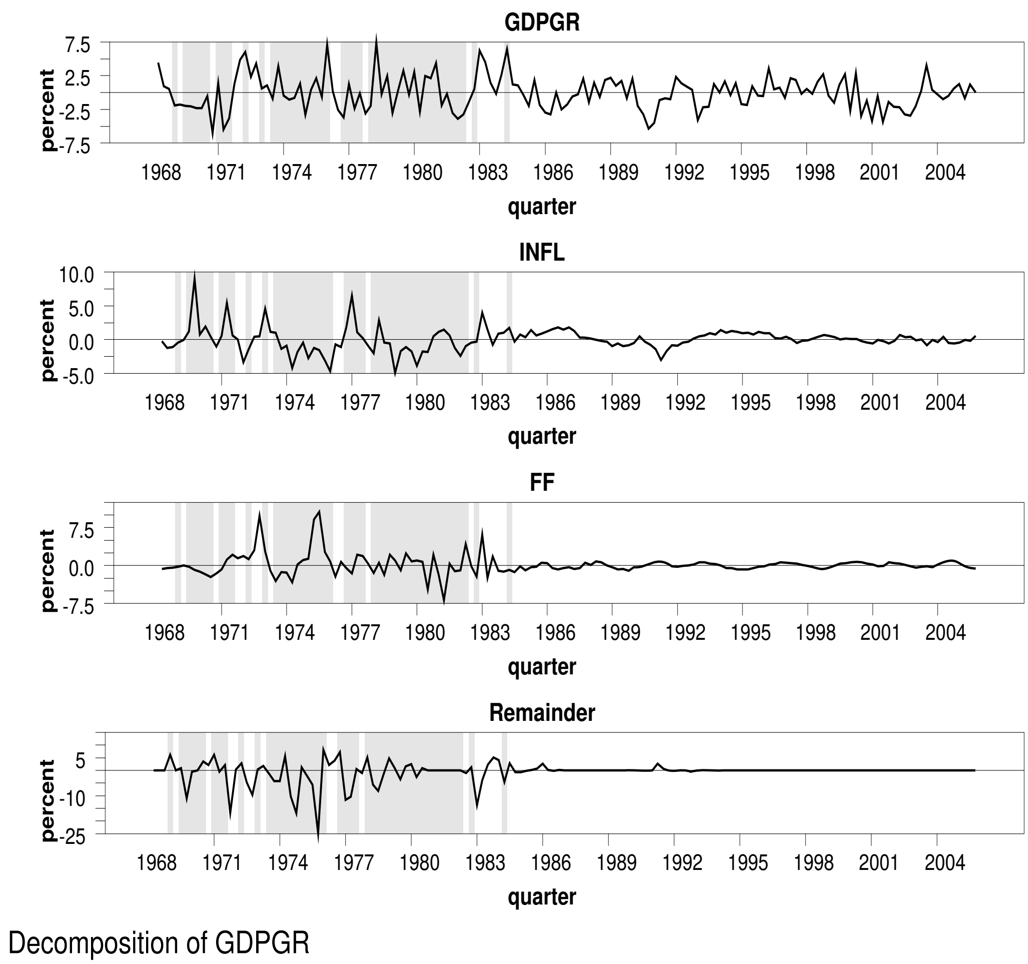

Figure 8: Forecast error in output growth attributed to shocks during previous twelve quarters.

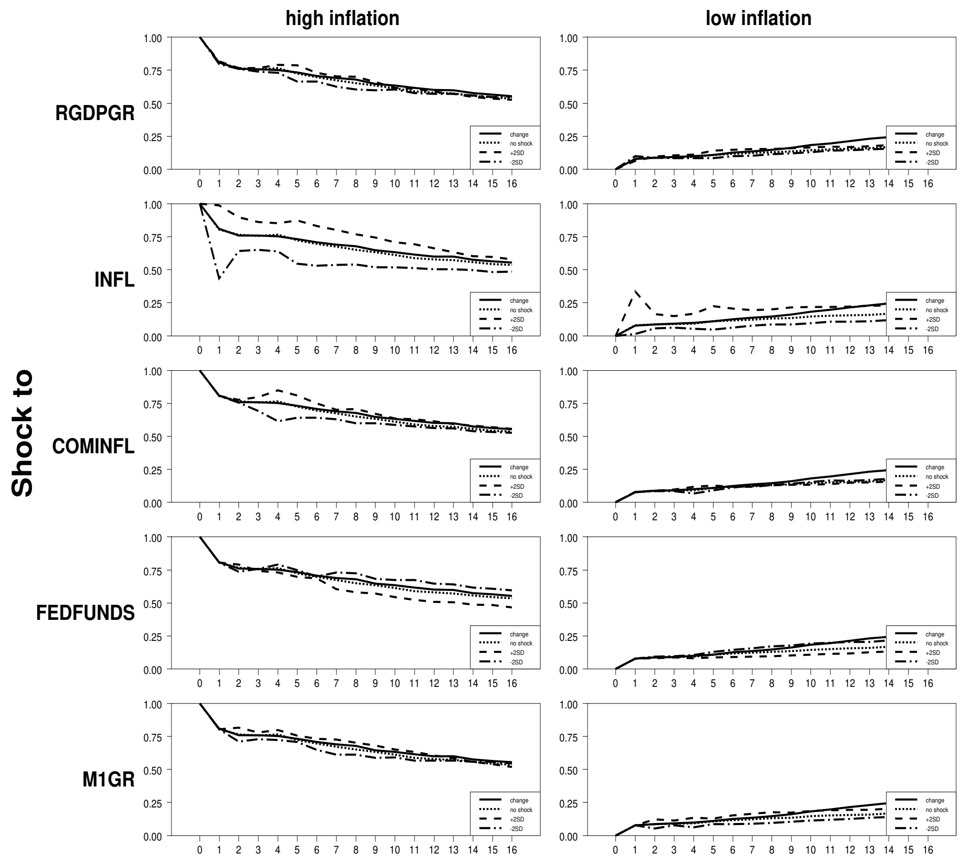

Figure 9: Probability of high inflation regime conditional on starting regime. Federal Funds Rate equation interchanged (solid line).

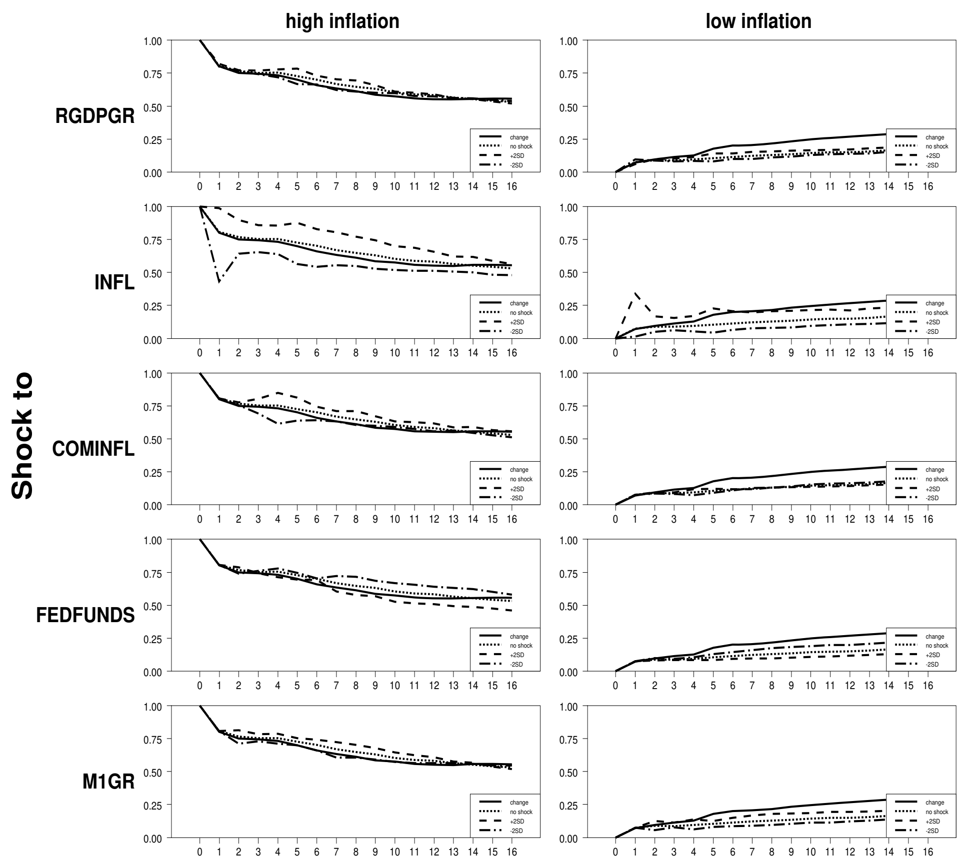

Figure 10: Probability of high inflation regime conditional on starting regime. Output equation interchanged (solid line).

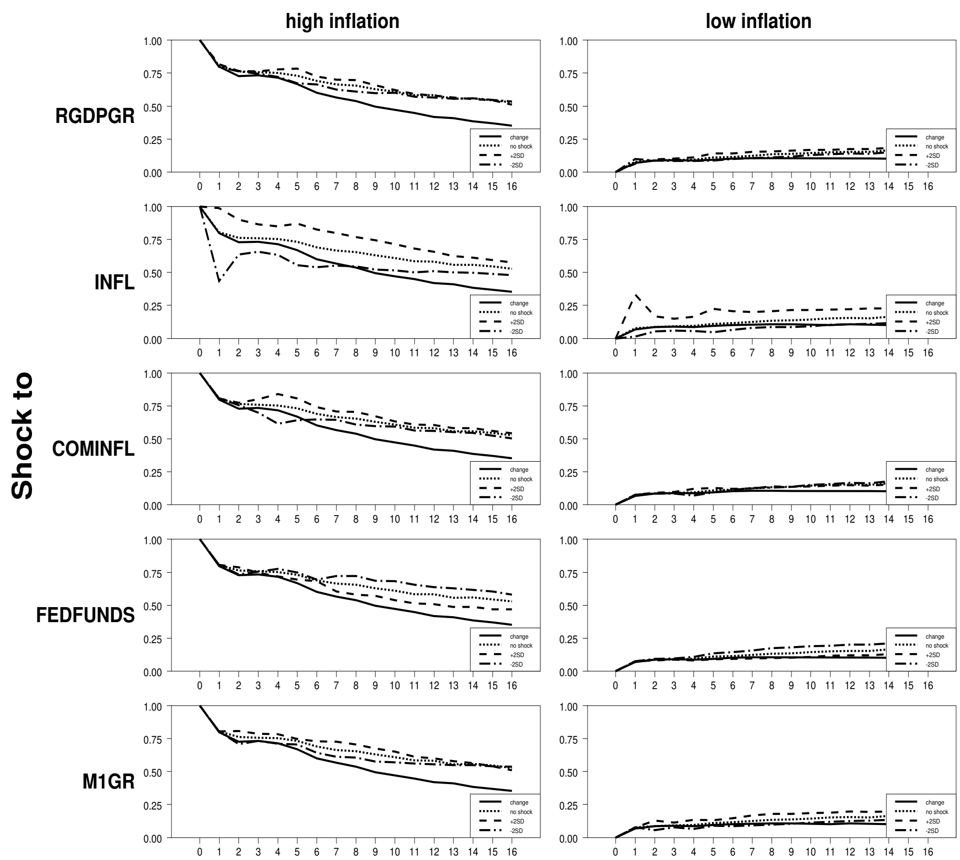

Figure 11: Probability of high inflation regime conditional on starting regime. Inflation equation interchanged (solid line).