The Instability in the Monetary Policy Reaction Function and the Estimation of Monetary Policy Shocks[*†]

N. Kundan Kishor
University of Wisconsin-Milwaukee

Monique Newiak
Ludwig-Maximilians University Munich

Abstract

We extend Romer and Romer's (2004) analysis of the estimation and the effects of monetary policy shocks by (i) controlling for changes in the monetary policy reaction function and (ii) changes in the response of output and prices over time with an extended data set. The results suggest that the post 1979 responses of output and prices to a monetary policy shock are significantly different from what has been reported for the whole sample: While output and prices respond significantly and negatively if their response is estimated for the whole sample period (1969-2005), the response of output is insignificant for the period of 1979-2005, and the response of prices is much weaker. The analysis of the changes in the monetary policy conduct over time allows us to partly attribute the diminished price and output responses to a successful monetary policy which led to a less volatile economy during the great moderation.

[*]Kishor: Department of Economics, Bolton Hall, Box 0413, University of Wisconsin-Milwaukee, Milwaukee, WI-53201 (Email: kishor@uwm.edu). Newiak: Ludwig-Maximilians University Munich, Department of Economics, Munich Graduate School of Economics, Kaulbachstraße 45, 80539 Munich, Germany (Email: info@monique-newiak.de)

[†]Newiak gratefully acknowledges financial support from the German Research Foundation through GRK 801.

1 Introduction

Monetary policy is not exogenously given, but largely driven by policy makers' reactions to macroeconomic conditions[1]. In order to measure the impact of monetary policy, we thus need to estimate its component that does not respond endogenously to the changes in the macroeconomic environment. To overcome the problem of endogeneity, different approaches have been proposed. One notable approach is the identification of monetary policy shocks by Romer and Romer (2004), who derive their measure of monetary policy shocks by regressing changes in the intended federal funds rate on Greenbook forecasts of output growth, inflation and the unemployment rate for every regular Federal Open Market Committee (FOMC) meeting in the period between 1969 and 1996.[2] The residuals from this regression are the changes in the federal funds rate target not taken in response to information about future economic developments and thus constitute a measure of monetary policy shocks.

The results of Romer and Romer's analysis are appealing from a theoretical point of view: the "price puzzle", i.e. the positive response of prices to a monetary policy shock, disappears, and output temporarily declines in response to a contractionary monetary policy shock. However, their work is based on two simplifying assumptions: firstly, they assume that monetary policy makers' response to movements in inflation and output has not changed for the whole sample, and secondly, that the response of prices and output to monetary policy shocks remained the same over time. These assumptions contradict the recent literature which finds evidence of a change in the monetary policy reaction function[3] and a change in the response of output and prices to monetary policy shocks[4] within the examined period.

In this paper, we therefore extend Romer and Romer's (2004) analysis of the impact of monetary policy on output and prices by (1) accounting for the fact that monetary policy

[1] Bernanke, Gertler and Watson (1997).

[2] Other popular approaches include the recursive VAR approach of Christiano, Eichenbaum, and Evans (1996), the structural VAR approach of Bernanke and Mihov (1998) and Boivin and Giannoni (2006), and the Federal Funds Futures market approach of Kuttner (2001).

[3] Clarida, Gali and Gertler (2000), Orphanides (2001, 2002, 2004).

[4] See the NBER working paper version (no. 5145, June 1995) of Bernanke and Mihov (1998), Barth and Ramey (2000), Boivin and Giannoni (2002, 2006), Gertler and Lown (2000), Kishor and Kochin (2006), and Kuttner and Mosser (2002).

makers' response to macroeconomic conditions has changed since Paul Volcker took over the chairmanship of the Federal Reserve in 1979, and (2) recognizing that the macroeconomic stability experienced in the U.S. after 1979 might have changed the response of output and prices to monetary policy shocks. After providing econometric evidence for a break in the monetary policy reaction function, we use Romer and Romer's methodology to derive monetary policy shocks for the pre-1979 and post-1979 periods by estimating different monetary policy reaction functions for both sample periods. We then show that the response of output and prices to a monetary policy shock has changed significantly around 1980. Based on the results, we are then able to attribute the changes in the price and output responses to changes in the conduct of monetary policy.

Our findings suggest that ignoring the instability in the monetary policy reaction function can provide a misleading impression of the effects of monetary policy for the whole sample. We find that the estimates of monetary policy shocks for the whole sample are disproportionately affected by the pre-1979 period shocks. Thus the response of output and prices to a monetary policy shock for the whole sample reported by Romer and Romer (2004) mainly reflects the impact of the shocks estimated from the first sub-sample. Accounting for the instability in the monetary policy reaction function and estimating the response of output and prices for both periods separately reveals that output and prices reacted differently to a monetary policy shock after 1979 than reported by Romer and Romer (2004) for the whole sample. In particular, we show that the response of output to a monetary policy shock is insignificant after 1979, and the response of prices is significantly smaller than for the whole period. Based on the estimation of the monetary policy responses to output and inflation forecasts we then argue that these results can be attributed at least partially to a more stabilizing monetary policy in the post-1979 era.

The next section gives a short overview of the related literature, in Section 3 we estimate monetary policy functions in order to derive the monetary policy shocks. In Sections 4 and 5, we estimate the responses of output and prices using our new shock series and perform different robustness checks. Section 6 argues that the decline in the output and price response can be partly attributed to a more stabilizing monetary policy. Section 7 concludes the paper.

2 Related Literature

The approach we take in this paper is supported by the recent literature on the changes in the conduct of the U.S. monetary policy around 1979 and the change in its effectiveness around 1980.

Clarida, Gali and Gertler (2000) estimate a forward-looking policy rule for the periods before and during the Volcker-Greenspan era in order to evaluate monetary policy's effectiveness. Their results suggest that in the period before 1979 monetary policy was too accommodative, whereas after 1979, beginning with Paul Volcker's regime, monetary policy played a stabilizing role in containing inflation. Orphanides (2000, 2001 and 2004) criticizes Clarida, Gali, and Gertler's results on the ground that monetary policy makers are constrained by the availability of the real-time data. He argues that the use of revised data in their paper provides misleading estimates of the monetary policy reaction function's coefficients. Orphanides' results indicate that it was the aggressive response to movements in the output gap that might have created the inflationary environment in the pre-1979 era, as the response to inflation was not statistically different across different sub-periods. Though the conclusions of the papers are certainly different, both approaches reveal that the policy-makers' response to changes in macroeconomic variables has changed over time.

In another stream of literature, it has been argued that the response of output and prices to monetary policy has declined around the 1980s (Bernanke and Mihov (1998)[5], Boivin and Giannoni (2002, 2006)). The decline in the impact of monetary policy shocks on output does not necessarily imply a reduction in the potency of monetary policy, but, on the contrary, may itself be the result of a very successful monetary policy: If the systematic component of monetary policy is perfectly successful, then the goal variables including output and prices would become a constant and a zero correlation between monetary policy shocks and output and prices would be observed (Kishor and Kochin, 2006). Using a structural

[5] NBER working paper version (no. 5145, June 1995)

VAR model, Boivin and Giannoni (2006) show that the diminished response of output and prices to monetary policy shocks can be explained by an increase of the Fed responsiveness to inflation expectations, and Senda (2005) shows that the reduction in the volatility of output and inflation has been caused by a more aggressive response of the Federal Reserve to macroeconomic fluctuations.

We contribute to the above literature in two ways: First, by bringing 9 years of additional data to bear to Romer and Romer's analysis, we provide additional evidence about the specific changes in the conduct of monetary policy and the different responses of output and prices to monetary policy shocks over time. Second, the analysis of the changes in monetary policy allows us to partially attribute this change in the responses to a more aggressive systematic monetary policy.

3 Estimation of Monetary Policy Shocks

In this section, we briefly review Romer and Romer's methodology of deriving the monetary policy shocks and re-estimate the monetary policy reaction function for the extended data set (1969-2005). We then show that there has been a break in the conduct of monetary policy and compare the resulting estimates for the different subsamples. Finally, we show the effect of this change in the estimation of monetary policy makers' reactions on the monetary policy shock series.

Following Romer and Romer (2004), we derive the monetary policy shocks by regressing the changes in the federal funds rate target Δff_m around meeting m on the federal funds rate target before the meeting ffb_m, the current Greenbook forecasts of inflation $\widetilde{\pi}_{mi}$, output growth $\Delta\widetilde{y}_{mi}$ (past quarter, current quarter and two quarters ahead) and the unemployment rate $\widetilde{u}_{m0}$ (current quarter) as well as changes of these forecasts compared to the last meeting's predictions[6]:

$$\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \Delta\widetilde{y}_{mi} + \sum_{i=-1}^{2} \lambda_i (\Delta\widetilde{y}_{mi} - \Delta\widetilde{y}_{m-1,i}) + \sum_{i=-1}^{2} \varphi_i \widetilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i (\widetilde{\pi}_{mi} - \widetilde{\pi}_{m-1,i}) + \rho \widetilde{u}_{m0} + \varepsilon_m. \quad (1)$$

The residuals ε_m from the estimation of (1) represent the component of monetary policy that does *not* represent the component of monetary policy that is made in response to macroeconomic conditions. They are therefore treated as the measure of monetary policy shocks.

The second column of table 1 shows the results of the estimation of equation (1) for the whole sample period (1969-2005). Though our sample contains nine more years of data compared to Romer and Romer's (2004) original sample (their results are in the first column of the table), our results are very similar to their findings: The sum of the coefficients on the Fed's response on the output forecasts is 0.05 ($t = 3.3$). This implies that if the output growth forecasts change by one percentage point for the four quarters of interest, then the federal funds rate will be increased by 5 basis points. The response to the inflation forecasts is of same magnitude (0.04 with $t = 2.8$). The strongest response is on changes in the forecasts of output growth (sum of the coefficients is 0.21 with $t = 4.6$), while the response to changes in the inflation forecasts is insignificant. The negative and significant coefficient on the unemployment forecasts confirms the countercyclical behavior of the monetary policy responses.

We now plot the cumulated monetary policy shock series computed from this single monetary policy function in Figure 1. The plot reveals the problem associated with Romer and Romer's (2004) estimation of monetary policy shocks by using a single monetary policy reaction function spanning the whole time period. Shocks are either persistently negative or positive with an obvious turning point around 1979. Keeping in mind that the monetary policy shocks are the residuals from a monetary policy reaction function, the interpretation

[6]The Greenbook forecasts are prepared by the Federal Reserve staff and presented to the members of the FOMC about one week before every regular FOMC meeting.

of this graph is straight forward. Since a monetary policy shock is the difference between the intended federal funds rate and the fitted value of the intended federal funds rate, we get consistently negative values of the residuals for the pre-1979 period. By construction, the use of the whole sample leads to a lower value of the fitted federal funds rate in the second sub-sample, and hence the residuals are consistently positive. The use of the full sample to estimate the monetary policy shocks would give the impression of a more aggressive response to inflation and real activity movements than it originally was during the first sample.

The impression from Figure 1 is confirmed by formal break tests. In particular, we use the Bai-Perron (1998) test for a structural break with different combinations of up to 10 coefficients from equation (1). The results are given in Table 2. For each parameter combination the test reveals that a break has occurred around observation 136 which is an FOMC meeting early in 1980, i.e. shortly after Paul Volcker took over the chairmanship of the Federal Reserve. Andrews' (1993) test for parameter instability confirms that there has been a policy break around that time[7]. This break date is also consistent with the literature on the estimation of monetary policy reaction functions in which authors like Clarida, Gali and Gertler (2000) and Orphanides (2000,2001,2004) estimate different reaction functions for the pre-Volcker and the Volcker-Greenspan periods.

As the results of the break tests indicate that the FOMC's response to unemployment, output and inflation forecasts as well as their reaction to changes in these forecasts and the persistence of the federal funds rate target have changed, we estimate two different monetary policy function for the time before and beginning with Paul Volcker's chairmanship. The results are given in the third and the fourth columns of Table 1.

We clearly see that the FOMC's response to output growth and inflation forecasts are different for the two periods: The cumulated responses to output growth forecasts have more than doubled (the sum of the coefficients on output growth forecast changed from 0.07 to 0.16 with increased t-statistic from 3.5 to 5.1). While for the first sub-sample none of the individual coefficients on output growth was individually significant, the one period ahead

[7]Not reported to save space, available upon request.

forecast on output growth becomes significant at the 5% level for the second sub-sample. The coefficient on the one-quarter ahead forecast on inflation which has been negative for the first sub-sample, is large (0.13) and significant for the second sub-sample. The overall response to inflation increased to a high of 0.18 ($t = 5.4$) compared to a low of 0.06 ($t = 1.8$) in the period before. In the first sub-sample, policy makers seemed to rather react to changes in inflation forecasts (large coefficient of 0.14 on changes in one quarter ahead forecasts with $t = 1.9$), whilst in the second sub-sample changes in these forecasts were followed more by procyclical movements (coefficient of -0.15 in the latter period with $t = -1.78$). The response to changes in the output forecasts is larger in the second sub-sample (0.16 vs. 0.12), and the response to the unemployment rate is of about the same magnitude.

These results suggest that the conduct of monetary policy has changed dramatically with the start of Paul Volcker's chairmanship. How does the estimation of the monetary policy shocks ε_m with different monetary policy function influence the shock series? Figure 1 plots the cumulated shock series estimated from (1) with the two different sub-periods. It reveals that our new shock series does not contain long periods in which monetary policy shocks are either predominantly positive or negative and thus does not contain large periods in which monetary policy is estimated systematically more loose of more conservative than it actually was. As will be shown in the next section, this change in the shock series has a strong impact on the responses of output and prices to the monetary policy shocks.

4 Output and Price Responses to Monetary Policy Shocks

In this section, we briefly describe the methodology of how the response of output and prices to monetary policy shock is computed. We then show that the extension of the sample with additional nine years does not alter the general results obtained by Romer and Romer (2004), if the monetary policy shocks used to compute the output and price responses are derived from a single monetary policy function (1969-2005). We then show how the responses of output and prices change if we estimate them using different monetary policy functions and allow their responses to change over time.

In order to estimate the responses of output and prices to a monetary policy shock we follow Romer and Romer (2004) in estimating the following two base line regressions:

$$\Delta y_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta y_{t-i} + \sum_{j=1}^{36} c_j S_{j-t} + e_t \quad (2)$$

$$\Delta p_t = a_0 + \sum_{k=1}^{11} a_k D_{kt} + \sum_{i=1}^{24} b_i \Delta p_{t-i} + \sum_{j=1}^{48} c_j S_{j-t} + e_t. \quad (3)$$

In these equations y is the log of industrial production, p is the log of the producer price index (PPI) for finished goods, S is the measure of monetary policy shocks, and D_k are the monthly dummies.[8] 24 lags of output growth and inflation are included into the regressions, and the measure of monetary policy shocks enters the output and price responses with 36 and 48 lags, respectively. The response of output and prices to a one time shock in the policy variable S of one percentage point is then examined. To obtain the whole impact of the monetary policy shock, the estimated coefficients have to be summed up: The response for e.g. log output in month one is c_1, for month 2 it is $c_1 + (c_2 + b_1 c_2)$ etc.

The results of the estimation conducted on the basis of monetary policy shocks estimated from a single monetary policy function spanning the whole period (1969-2005) are shown in Table 3. As in Romer and Romer (2004), the coefficients on the monetary policy shocks in the output response regression are mostly insignificant and not throughout negative, but adding the nine additional years to the sample increased the number of positive coefficients even further. The cumulative output response is plotted in Figure 3. To make the graphs comparable to Romer and Romer, the responses are plotted with their one-standard-error bands. The graph gives qualitatively the same response as shown by Romer and Romer (2004): The cumulated output response becomes negative after six months and declines gradually until reaching its peak in month 27 with -2.6%, the response gradually declines afterwards, and output is back to its initial level before month 48.

However, the magnitude and the length of the output response is notably smaller than has been reported by Romer and Romer (2004) for the shorter sample of 1969-1996: The

[8] The data set is described in the data appendix.

maximum response is much smaller than their reported −4.3%, and output is back to its initial level after 48 months, while in Romer and Romer's (2004) results the response is still at approximately −2% after four years[9].

The same pattern arises for the price response for which the coefficient estimates are also given in Table 3, and the cumulated responses are plotted in Figure 4. As in Romer and Romer (2004), the cumulated response of prices to a monetary policy shock is insignificant for the first 21 months and gradually becomes larger in magnitude and significant after that. However, as in the case of the output response, the response of prices using the larger sample is smaller as compared to Romer and Romer (2004). While they report a price response of −5.9% after 48 months, we find a price response of only about −4.7% for that period.

Using the monetary policy shocks estimated from a single monetary policy function spanning 1969-2005 thus provides qualitatively the same results as reported in Romer and Romer (2004) for the period of 1969-1996, but with somewhat diminished magnitudes of the output and price responses.

The results are entirely different if the responses are estimated with monetary policy shocks derived from separate monetary policy functions. The estimated reactions of output and prices for the period 1979-2005 are given in Table 4: The coefficients on the monetary policy shocks in the output regression (2) are throughout tiny, about half of them is positive, and non of the negative coefficients is individually significant on the 5% level. Though the coefficients on the price response are also small, the majority of them is negative (though most of the coefficients are again individually insignificant).

The cumulated responses of output and prices for the period 1979-2005 are plotted in Figures 5 and 6. We do not report the results for 1969-1979, because, given the large number

[9]We follow Romer and Romer (2004) in calculating the standard errors. The standard errors are calculated using a Monte Carlo experiment where we artificially generate data for the two response equations using the estimated distributions of the estimated coefficients. For each draw, we estimate the response of output and price to a monetary policy shock at different horizons. The standard error for the response at month h is then the standard deviation across the different draws of the estimated responses at month h. The number of draws for our exercise is 500.

of coefficients to be estimated, the number of degrees of freedom is too small to give reliable results. The output response to a monetary shock is basically zero in the first year, and throughout positive, tiny and insignificant. For most of the periods, the t-statistic is smaller than one and, except for the very first period, never exceeds 1.4). The price response is tiny for the first 27 months and becomes larger in magnitude afterwards. However, compared to the estimates for the whole sample, the price response is much smaller (e.g., for month 48 the response is -3.2% compared to -4.7% for 1969-2005 and -5.9% reported by Romer and Romer (2004)). Except for four months within the first 12 months of the price response, the t-statistic on the cumulated price responses never exceeds 1.6. Consequently, the price response has declined in magnitude and in significance.

We emphasize that the diminished significance of the responses compared to the results of Romer and Romer (2004) is *not* due to a shorter sample: While we exclude the years 1969-1979 from the analysis, we extend the data set at the other end by adding the years 1997-2005.

The possible implications of these changes in both, the output and the price responses, are discussed in Section 6.

5 Robustness Check

In this section we perform two experiments to test the robustness of our results. First, we test whether the elimination of the volatile period (1979-1982) in our sample affects the estimated output and price responses to monetary policy shock significantly. It has been argued that the period of non-borrowed reserves targeting (1979-1982), also known as the "Volcker Experiment" was a period of excessive volatility, and it might have played a big role in the estimation of monetary policy shocks. This problem has been emphasized by Bernanke and Mihov (1998), who state that the federal funds rate should not be used as a monetary policy indicator for the time period between 1979 and 1982. Although none of the break tests on the coefficients of equation 1 indicates a break at the end of 1982, we want to make sure that the dynamic responses reported above are not driven by the huge variation in the monetary shocks from this short sample. We therefore re-estimate the responses of output and prices by excluding the Volcker experiment period (1979-1982). The cumulated response of output to the monetary policy shock stays insignificant for 47 out of 48 periods (the exception is, as before, the very first period), and non of these 47 insignificant responses have a t-value exceeding 1.1. The price response is even smaller in magnitude than for the period 1979-2005, and all but four negative responses in the first year are not significant at any conventional significance level. Our results thus not only hold if the years of non-borrowed reserves targeting are excluded, they become even stronger.

As a further robustness check, we follow Romer and Romer (2004) and estimate the effect of a monetary policy shock on prices and output a VAR which includes three variables; the log of industrial production, the log of the PPI for finished goods and the measure of the monetary policy shock derived from the method described in section 3.[10] 36 lags are included into the estimation. Since the federal funds rate enters the VAR in levels, the monthly shocks are cumulated. We report the responses of output and prices to a one percentage point innovation in the monetary shock in Figures 7 and 8 together with the two-standard-error bands. Figure 7 plots the impulse-response functions for output and prices for the case in which a single monetary policy function is used for the estimation of the shocks and the responses are estimate for the whole period 1969-2005. Comparing this figure with figures 3 and 4 reveals that the responses are very similar to the responses estimated with the original approach in section 4, but they are a little smaller in magnitude. Figure 8 gives the responses of output and prices for the period 1979-2005 using the monetary shock series derived from a monetary policy reaction function from 1979-2005. Again, the VAR impulse-response functions confirm the results of the previous section: The price response is smaller in magnitude, and the output response is close to zero and insignificant except for the first three periods. Thus the results from the VARs confirm our previous findings.[11]

[10]The description of the data used in this paper is given in the Data Appendix.

[11]We do not report the detailed results for the VAR and impulse-response analysis for the sake of brevity. The results are available upon request.

6 Has Monetary Policy Lost its Effectiveness?

The empirical evidence presented in the previous sections suggests that the response of output and prices to monetary policy shocks has declined considerably since 1980. Does this imply that the Federal Reserve has partly lost its effectiveness in controlling the economy? Our results certainly do not imply that. In fact, the reduction in the response to monetary policy shocks may result from the success of *systematic* monetary policy in dampening economic fluctuations. To illustrate this point, consider an extreme example. If monetary policy is perfectly successful, then it would make the goal variable (output or price) a constant[12]. By construction, a constant is uncorrelated with any variable, and thus it will be uncorrelated with monetary policy shocks. Therefore if systematic monetary policy was perfectly successful in stabilizing the economy, we would not find any correlation between monetary policy shocks and inflation and output.

To stress this point, we consider a simple New Keynesian model with a dynamic IS-curve (4) and the New Keynesian Phillips curve (5)[13]:

$$y_t = E_t y_{t+1} - \sigma r_t + g_t, \quad \sigma > 0 \tag{4}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa y_t + u_t, \tag{5}$$

in which y_t is output, π_t is the rate of inflation, and r_t is the real interest rate. All variables are in terms of percent deviations from their long-run values. Output is negatively correlated with the real interest rate and also depends on expected future output, as consumers want to smooth their consumption over time. The parameter σ is associated with the elasticity of intertemporal substitution in consumption. Inflation depends positively on future expectations about inflation (discounted with the time preference factor β) and is positively linked to the IS-curve through the output gap. The positive parameter κ summarizes a plethora of parameters from the New Keynesian model.[14] The zero-mean disturbance terms g_t and

[12]Kishor and Kochin (2007).
[13]Clarida, Gali, Gertler (1999).
[14]For details and the derivation of the two equations see Gali (2008).

u_t can be interpreted as demand and cost-push shocks, respectively. Iterating equation (1) forward, we obtain

$$y_t = -\sigma r_t^L + g_t \tag{6}$$

in which $r_t^L = E_t \sum_{j=0}^{\infty} r_{t+j}$ represents the long-run real interest rate which is determined by the expected path of the short-term interest rates. Equation (6) implies that output is determined by the long-run interest rate. Similarly, we can iterate (5) forward and find that inflation is determined by a weighted sum of expected deviations of output from its natural level:

$$\pi_t = E_t \left[\sum_{k=0}^{\infty} \beta^k \kappa y_{t+s} \right] + u_t. \tag{7}$$

In our example, the central bank conducts monetary policy by setting short-term interest rates. Monetary policy actions can alter the path of expected short-term interest rates, and hence influence the long-term interest rate. Suppose that monetary policy follows an interest rate rule of the following type (see Taylor (1993)):

$$r_t = \phi_y y_t + \phi_\pi \pi_t + \varepsilon_t. \tag{8}$$

ϕ_y and ϕ_π represent the magnitudes of the response of the central bank to deviations of output from its natural level and to inflation. ε_t is the monetary policy shock which is assumed to be uncorrelated with the demand shock g_t and the cost-push shock u_t. Combining equations (6), (7) and (8), we obtain

$$y_t = \frac{g_t - \sigma\phi_\pi u_t - \sigma\varepsilon_t}{1 + \sigma\phi_y + \sigma\kappa\phi_\pi} \tag{9}$$

$$\pi_t = \frac{\kappa g_t + (1 + \sigma\phi_y)u_t - \sigma\kappa\varepsilon_t}{1 + \sigma\phi_y + \sigma\kappa\phi_\pi}. \tag{10}$$

The above expressions imply that equilibrium output and inflation depend on demand, cost-push and monetary policy shocks, as well as on the parameters σ, κ, ϕ_y and ϕ_π. An unexpected unit increase in the short-term interest rate ($\varepsilon_t = 1$) reduces equilibrium output by $\sigma/(1+\sigma\phi_y+\sigma\kappa\phi_\pi)$, and decreases inflation by $\sigma\kappa/(1+\sigma\phi_y+\sigma\kappa\phi_\pi)$. Therefore a reduction in the impact of monetary policy shocks can arise through different channels: a reduction in σ

or κ or a higher value of ϕ_y or ϕ_π. If monetary policy has become less potent, then, the lower output response is due to a smaller elasticity of intertemporal substitution in consumption or due to an increase in the slope of the Phillips curve. If the lower output response is due to higher values of ϕ_y or ϕ_π, then the lower response of output to monetary policy shocks reflects the greater willingness on the part of the monetary policymakers to neutralize fluctuations in output and inflation. In this case, the decreased responses of output and inflation to monetary policy shocks do not imply that monetary policy has lost its effectiveness.

While we do not test for changes in σ or κ in this paper, the results section 3 clearly reveal a change in the monetary policy conduct around 1979. In particular, we could show that the responses to output growth and inflationary forecasts have increased significantly with the beginning of Paul Volcker's chairmanship. In the just presented model, this increase would be reflected in an increase in the parameters ϕ_y and ϕ_π. The lower responses of output and inflation to monetary policy shocks can be thus at least partially attributed to a more stabilizing conduct of the systematic part of monetary policy.

Our results thus support the part of the monetary policy literature which suggests that the Federal Reserve has responded aggressively to expected movements in output and inflation to stabilize the economy since 1980[15] and the stream of the literature which argues that the Federal Reserve has been more successful in stabilizing output and inflation after 1979.[16]

7 Conclusions

In this paper, we revisit the estimation of monetary policy shocks using the methodology of Romer and Romer (2004) for a sample that runs from 1969 through 2005. Romer and Romer (2004) assume similar responses of the Federal Reserve to movements in inflation and the output gap and the same responses of output and inflation to monetary policy shocks over time. Using a longer sample, we extend their approach by following the strong evidence

[15] Clarida, Gali, and Gertler (2000), Boivin and Giannoni (2002, 2006), Favero and Rovelli (2003), Senda (2005).

[16] For example, Barth and Ramey (2000), Boivin and Giannoni (2002, 2006), Gertler and Lown (2000), Kishor and Kochin (2006), and Kuttner and Mosser (2002).

in the literature about (i) a change in the monetary policy conduct with the appointment of Paul Volcker as the chairman of the Federal Reserve and (ii) about the change in the responses of output and prices to monetary policy shocks.

After applying formal break tests, we estimate separate monetary policy reaction functions for the two sub-samples and show that the Federal Reserve's response to economic forecasts has increased remarkably after 1979. We then use the new shock series to estimate the response of output and prices to the exogenous part of monetary policy for the post-1979 period. We find that monetary policy shocks from the pre-Volcker sub-sample disproportionately affect the results in the original Romer and Romer (2004) approach.

The results from the estimation for the post-1979 era are significantly different from what has been reported by Romer and Romer (2004) for the whole sample. In contrast to Romer's and Romer's findings for the whole sample, our results show that the response of output to a monetary policy shock in the second period is very small and insignificant for the Volcker-Greenspan era. While the price response does not lose all its significance, its magnitude is much smaller as compared to the whole sub-sample. Eliminating the three years of non-borrowed reserves targeting from the sample even sharpens these results. We stress that the decline in the response of output and inflation does not mean that monetary policy has become less effective after 1979. On the contrary, we show that the lack of response to the *unsystematic* part of monetary policy can be at least partly attributed to the success of the *systematic* part of monetary policy by responding more aggressively to forecasts of the economic indicators.

References

[1] Barth, Marvin, and Valerie A. Ramey (2001), "The Cost Channel of Monetary Transmission", NBER Macroeconomics Annual 2001.

[2] Bernanke, Ben S., and Alan S. Blinder (1992), "The Federal Funds Rate and the Channels of Monetary Transmission" The American Economic Review, Vol. 82, No. 4 (Sep.),

901-21.

[3] Bernanke, Ben S., Mark Gertler, Mark Watson, Christopher A. Sims, and Benjamin M. Friedman (1997), "Systematic Monetary Policy and the Effects of Oil Price Shocks", Brookings Papers on Economic Activity, Iss. 1, 91-157.

[4] Bernanke, Ben S., and Ilian Mihov (1998), "Measuring Monetary Policy", The Quarterly Journal of Economics, Vol. 113, No. 3 (Aug.), 869-902.

[5] Boivin, Jean, and Marc P. Giannoni (2002), "Assessing Changes in the Monetary Transmission Mechanism: A VAR Approach", Economic Policy Review, May, 97-107.

[6] Boivin, Jean, and Marc P. Giannoni (2006), "Has Monetary Policy Become More Effective?", The Review of Economics and Statistics, Vol. 88, No. 3 (Aug.), 445-62.

[7] Christiano, Lawrence, Martin Eichenbaum and Charles Evans (1996), "Monetary policy shocks: what have we learned and to what end?", In: Michael Woodford and John Taylor, eds, Handbook of Macroeconomics North Holland.

[8] Clarida, Richard, Jordi Gali, and Mark Gertler (1999), "The Science of Monetary Policy: A New Keynesian Perspective", In: Journal of Economic Literature, Vol. 37 (December 1999), 1661-07.

[9] Clarida, Richard, Jordi Gali and Mark Gertler (2000), "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory", Quarterly Journal of Economics, Vol. 115, No. 1 (Feb.), 147-80.

[10] Cochrane, John H. (1998), "What do the VARs Mean? Measuring the Output Effects of Monetary Policy", Journal of Monetary Economics, Vol. 41, Iss. 2 (Apr.), 277-300.

[11] Cochrane, John H. (2004), "Comments on 'A new measure of monetary shocks: Derivation and implications'", presented at NBER EFG meeting (July).

[12] Favero, Carlo A. and Riccardo Rovelli (2003), "Macroeconomic Stability and the Preferences of the Fed: A Formal Analysis, 1961-98", Journal of Money, Credit and Banking, Vol. 35, No. 4, 545-556.

[13] Gali, Jordi (2008): "Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework", Princeton University Press, Princeton, NJ.

[14] Gertler, Mark, and Cara S. Lown (2000), "The Information in the High-Yield Bond Spread for the Business Cycle: Evidence and Some Implications", NBER working paper no. 7549.

[15] Kahn, James A., Margaret M. McConnell, and Gabriel Perez-Quiros (2002), "On the Causes of the Increased Stability of the U.S. Economy", Economic Policy Review, May, 183-201.

[16] Senda, Takashi (2005), "Determining Output and Inflation Variability: Are the Phillips Curve and the Monetary Policy Reaction Function Responsible", Economic Inquiry, Vol. 43, No. 2, 431-453.

[17] Kishor, Kundan N., and Levis A. Kochin (2006): "The Success of the Fed and the Death of Monetarism", Economic Inquiry, Vol. 45, No. 1 (Jan.), 56-70.

[18] Kuttner, Kenneth N., and Patricia C. Mosser (2002): "The Monetary Transmission Mechanism: Some Answers and Further Questions", FRBNY Policy Review, May, 15-26.

[19] McConnell, Margaret M., and Gabriel Perez-Quiros (2000), "Output Fluctuations in the United States: What has Changed Since the Early 1980's?", The American Economic Review, Vol. 90, No. 5 (Dec.), 1464-76.

[20] Nakamura, Emi, and Jon Steinsson (2008), "Five Facts about Prices: A Reevaluation of Menu Cost Models", The Quarterly Journal of Economics, Iss. 4 (November), 1415-64.

[21] Orphanides, Athanasios (2001), "Monetary Policy Rules Based on Real-Time Data", American Economic Review, Vol. 91, No. 4 (Sep.), 964-85.

[22] Orphanides, Athanasios (2002): "Monetary Policy and the Great Inflation", American Economic Review, Vol. 92, No. 2 (May), 115-20.

[23] Orphanides, Athanasios (2004), "Monetary Policy Rules, Macroeconomic Stability and Inflation", Journal of Money, Credit and Banking, Vol. 36, No. 2 (Apr.), 151-75.

[24] Romer, Christina D., and David H. Romer (2004), "A New Measure of Monetary Shocks: Derivation and Implications", The American Economic Review, Vol. 94, No. 4 (Sep.), 1055-84.

[25] Taylor, John B. (1999), "Staggered Price and Wage Setting in Macroeconomics", in J.B. Taylor and M. Woodford eds., Handbook of Macroeconomics, chapter 15, 1341-97, Elsevier, New York.

Data Appendix

In order to make the results of the papers comparable we use the same data series as Romer and Romer (2004).

Derivation of the monetary policy shocks

For 1969 to 1996, we use the data set by Romer and Romer (2004), which is available at the http : //elsa.berkeley.edu/˜dromer/. For the time after 1996 we use the so called "Greensheets" (available at the Federal Reserve of Philadelphia's website) containing the Federal Reserve staff's internal forecasts of inflation (the implicit GDP deflator/GDP chain waited price index at an annual rate), output growth (percentage change in real GDP at an annual rate) and the unemployment rate. As the FOMC began stating its federal funds rate target explicitly in 1994, we use the announced federal funds rate target from the Federal Reserve Banks website as the measure of the intended federal funds rate.

The monetary policy shocks are derived for every regular FOMC meeting with available Greenbook forecasts (8 to 14 per year).

Measuring the impact of monetary policy shocks on output and inflation

As in Romer and Romer (2004), the measure of output in the response regressions and VARs is the log of the non-seasonally-adjusted index of industrial production (series B50001, available on the website of the Board of Governors). The measure of the price level is the log of the non-seasonally-adjusted producer price index (series WPUSO3000, available at the website of the Bureau of Labor Statistics). The series contain monthly data.

The monetary policy shocks derived from (1) are converted into monthly shocks by setting shocks equal to zero for months without regular FOMC meeting, and by summing shocks for months with more than one FOMC meeting. The shocks are cumulated for the VAR estimation.

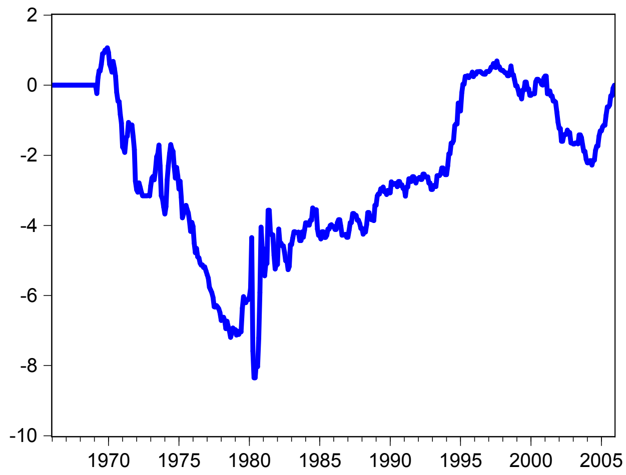

Figure 1: Cumulated monetary policy shocks, derived from single monetary policy function for 1969-2005.

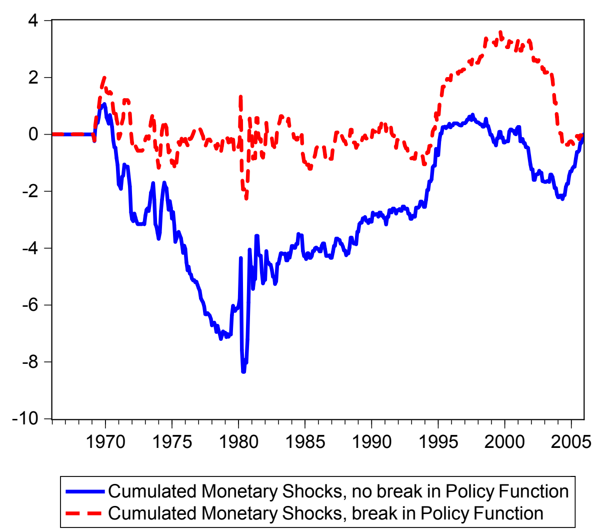

Figure 2: Cumulated monetary policy shocks for two different monetary policy functions (1969-1979 and 1979-2005) compared to one single function (1969-2005).

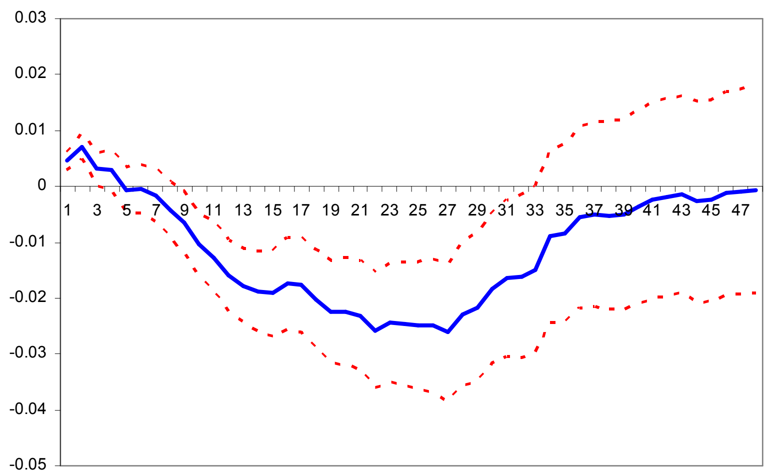

Figure 3: Cumulated output response to a one time 1% monetary policy shock for the period 1969-2005. Monetary policy shocks derived on the basis of a monetary policy function estimated for 1969-2005.

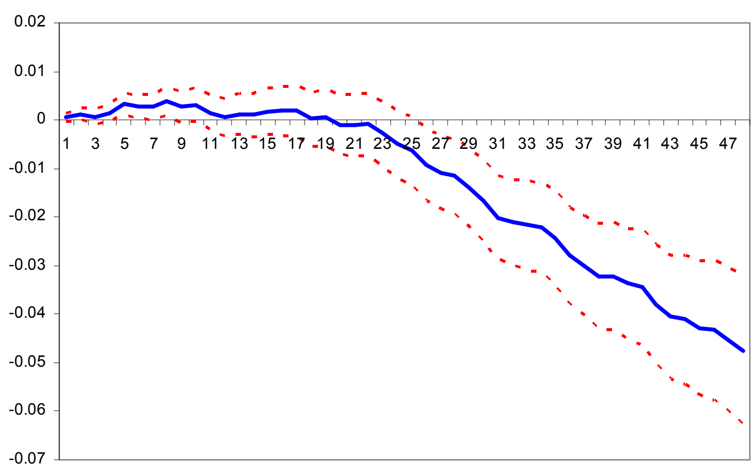

Figure 4: Cumulated price response to a one time 1% monetary policy shock for the period 1969-2005. Monetary policy shocks derived on the basis of a monetary policy function estimated for 1969-2005.

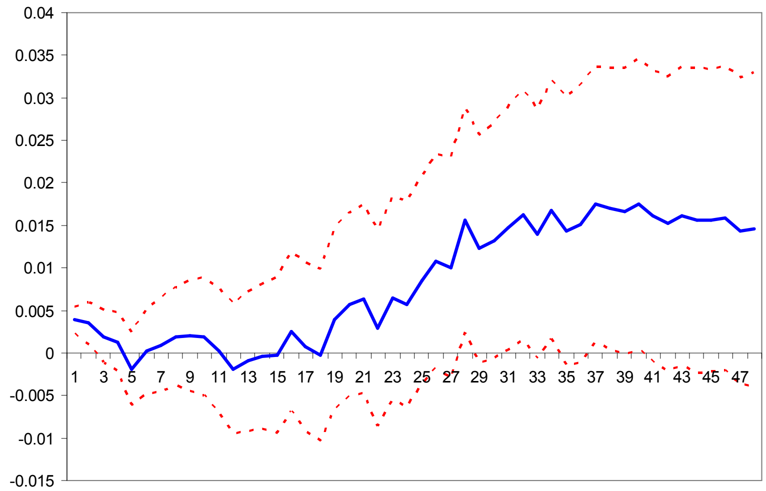

Figure 5: Cumulated output response to a one time 1% monetary policy shock for the period 1979-2005. Monetary policy shocks derived on the basis of a monetary policy function estimated for 1979-2005.

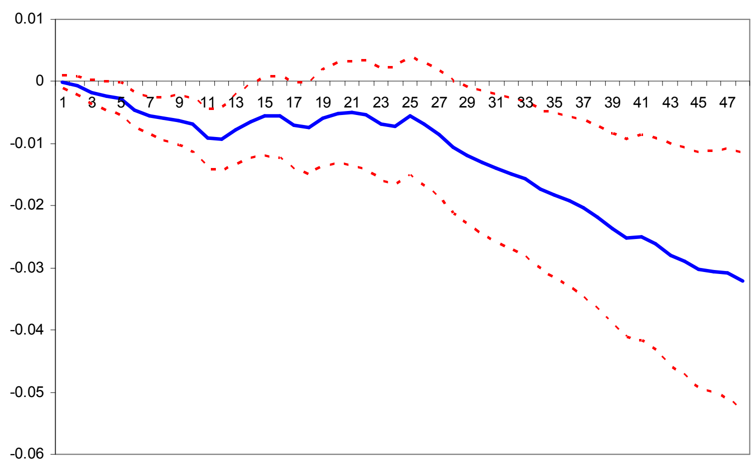

Figure 6: Cumulated price response to a one time 1% monetary policy shock for the period 1979-2005. Monetary policy shocks derived on the basis of a monetary policy function estimatedfor 1979-2005.

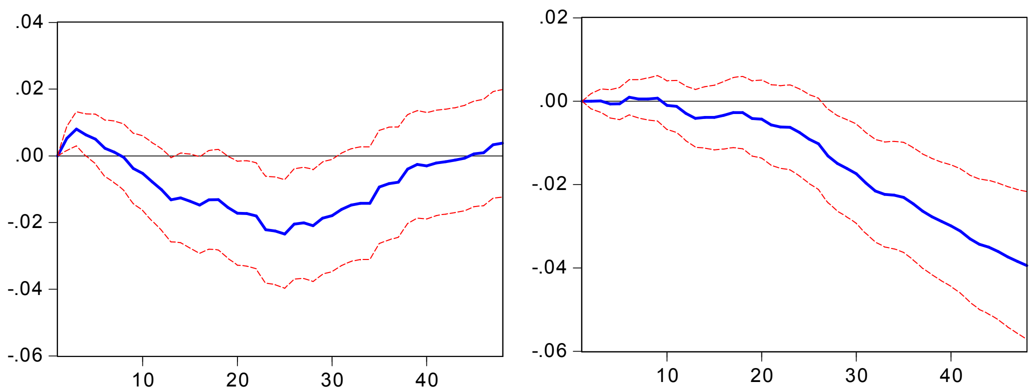

Figure 7: Responses of output and prices to a one unit innovation in the cumulated shock series for the period 1969-2005. Monetary policy shocks derived on the basis of a monetary policy function estimated for 1969-2005.

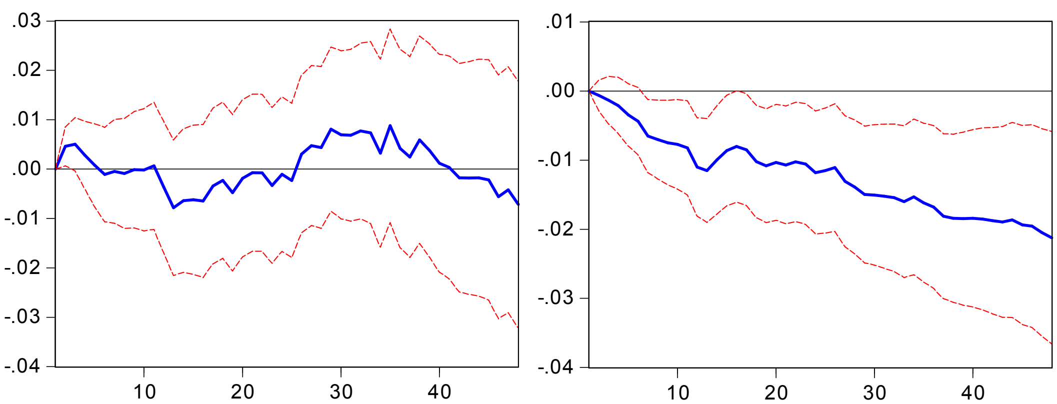

Figure 8: Responses of output and prices to a one unit innovation in the cumulated shock series for the period 1979-2005. Monetary policy shocks derived on the basis of a monetary policy function estimatedfor 1979-2005.

	1969-1996		1969-2005		1969-1979		1979-2005	
	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
Constant	0.171	0.141	0.116	0.103	0.173	0.269	-0.050	0.139
initial level federal funds rate	-0.021	0.012	-0.020	0.010	-0.026	0.026	-0.068	0.015
forecast output growth, quarters ahead:								
-1	0.007	0.010	0.008	0.009	0.011	0.009	0.006	0.016
0	0.003	0.019	0.006	0.016	0.007	0.016	0.031	0.027
1	0.010	0.032	0.021	0.026	0.014	0.027	0.091	0.040
2	0.022	0.032	0.012	0.026	0.033	0.028	0.032	0.039
change forecast output growth, since last meeting quarters ahead:								
-1	0.050	0.030	0.036	0.022	0.031	0.033	0.034	0.028
0	0.152	0.030	0.140	0.025	0.068	0.032	0.132	0.036
1	0.021	0.046	0.008	0.036	-0.023	0.043	-0.029	0.050
2	0.021	0.051	0.024	0.037	0.043	0.047	0.020	0.049
forecast inflation, quarters ahead:								
-1	0.021	0.024	0.033	0.020	0.016	0.023	0.065	0.034
0	-0.044	0.029	-0.046	0.025	0.021	0.030	-0.029	0.037
1	0.010	0.044	0.008	0.038	-0.067	0.047	0.126	0.058
2	0.052	0.047	0.047	0.041	0.092	0.045	0.023	0.067
change forecast inflation, since last meeting quarters ahead:								
-1	0.057	0.045	0.049	0.039	0.076	0.053	-0.010	0.050
0	0.003	0.048	0.011	0.038	0.011	0.050	-0.048	0.052
1	0.031	0.074	0.024	0.058	0.140	0.075	-0.150	0.084
2	-0.062	0.081	-0.064	0.070	-0.011	0.070	-0.086	0.113
forecast unemployment (current quarter)	-0.048	0.021	-0.044	0.017	-0.093	0.042	-0.084	0.024
n	263		335		121		214	
R^2	0.28		0.28		0.39		0.40	
$s.e.e.$	0.39		0.36		0.25		0.37	
DW	1.84		1.80		1.07		2.06	

Table 1: Monetary policy reaction functions for different time periods, estimated regression (1): $\Delta ff_m = \alpha + \beta ffb_m + \sum_{i=-1}^{2} \gamma_i \Delta\widetilde{y}_{mi} + \sum_{i=-1}^{2} \lambda_i(\Delta\widetilde{y}_{mi} - \Delta\widetilde{y}_{m-1,i}) + \sum_{i=-1}^{2} \varphi_i \widetilde{\pi}_{mi} + \sum_{i=-1}^{2} \theta_i(\widetilde{\pi}_{mi} - \widetilde{\pi}_{m-1,i}) + \rho\widetilde{u}_{m0} + \varepsilon_m$

Parameter allowed to have a break	UDmax Stat	Critical value	Break Date
β, ρ	12.84	11.15	136
$\beta, \gamma_{-1}, \gamma_0, \gamma_1, \gamma_2$	110.81	17.98	136
$\beta, \gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \varphi_{-1}, \varphi_0, \varphi_1, \varphi_2$	84.28	23.38	136
$\alpha, \beta, \gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \varphi_{-1}, \varphi_0, \varphi_1, \varphi_2$	65.98	26.62	136
$\gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \lambda_{-1}, \lambda_0, \lambda_1, \lambda_2, \rho$	607.52	24.99	136
$\beta, \gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \lambda_{-1}, \lambda_0, \lambda_1, \lambda_2, \rho$	88.72	26.62	136
$\gamma_{-1}, \gamma_0, \gamma_1, \gamma_2, \theta_{-1}, \theta_0, \theta_1, \theta_2$	449.19	21.41	138

Table 2: Bai-Perron break on monetary policy reaction function in equation (1) for the period 1969-2005: β is the coefficient on the federal funds rate target before the meeting, ρ is the coefficient on the current quarter unemployment forecast. γ_i and φ_i are the coefficients on the i quarters ahead forecasts on output growth and inflation, and λ_i and θ_i are the coefficients on the changes of the i quarters ahead forecasts of these variables compared to last meeting.

	Output response (Δy)				Price response (Δp)			
	Change in Output		Monetary Policy Shock		Change in Price		Monetary Policy Shock	
lag	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
1	0.028	0.052	0.005	0.002	0.209	0.053	0.001	0.001
2	0.028	0.052	0.002	0.002	-0.108	0.055	0.000	0.001
3	0.097	0.051	-0.004	0.002	0.020	0.055	-0.001	0.001
4	-0.002	0.052	0.000	0.002	-0.048	0.056	0.001	0.001
5	0.075	0.052	-0.004	0.002	0.070	0.055	0.002	0.001
6	-0.054	0.052	0.000	0.002	0.090	0.056	-0.001	0.001
7	0.043	0.051	-0.001	0.002	0.041	0.055	0.000	0.001
8	-0.000	0.051	-0.003	0.002	-0.017	0.055	0.001	0.001
9	0.043	0.051	-0.002	0.002	0.080	0.055	-0.001	0.001
10	-0.070	0.050	-0.004	0.002	-0.009	0.055	0.001	0.001
11	0.059	0.049	-0.002	0.002	0.168	0.055	-0.002	0.001
12	0.346	0.049	-0.003	0.002	0.096	0.055	-0.000	0.001
13	-0.017	0.050	-0.002	0.002	-0.140	0.055	0.000	0.001
14	-0.206	0.050	-0.001	0.002	0.076	0.055	-0.000	0.001
15	-0.131	0.050	0.000	0.002	-0.100	0.055	0.001	0.001
16	-0.089	0.051	0.002	0.002	-0.028	0.055	-0.000	0.001
17	0.090	0.051	0.000	0.002	0.030	0.055	0.000	0.001
18	0.051	0.051	-0.003	0.002	0.031	0.055	-0.001	0.001
19	0.053	0.051	-0.002	0.002	-0.011	0.054	0.000	0.001
20	0.023	0.051	0.000	0.002	0.016	0.055	-0.001	0.001
21	-0.053	0.051	-0.001	0.002	0.075	0.055	0.000	0.001
22	-0.038	0.050	-0.003	0.002	-0.055	0.055	- 0.000	0.001
23	-0.041	0.050	0.001	0.002	-0.090	0.055	-0.001	0.001
24	0.103	0.051	0.000	0.002	0.118	0.053	-0.002	0.001
25			0.000	0.002			-0.001	0.001
26			0.000	0.002			-0.003	0.001
27			-0.001	0.002			-0.001	0.001
28			0.003	0.002			-0.001	0.001
29			0.001	0.002			-0.002	0.001
30			0.003	0.002			-0.002	0.001
31			0.002	0.002			-0.003	0.001
32			0.000	0.002			0.000	0.001
33			0.001	0.002			-0.001	0.001
34			0.006	0.002			0.000	0.001
35			0.000	0.002			-0.001	0.001
36			0.003	0.002			-0.002	0.001
37							-0.001	0.001
38							-0.001	0.001
39							0.000	0.001
40							-0.001	0.001
41							0.000	0.001
42							-0.003	0.001
43							-0.001	0.001
44							0.000	0.001
45							-0.001	0.001
46							0.000	0.001
47							-0.001	0.001
48							-0.001	0.001
n				444				432
R^2				0.83				0.48
s.e.e.				0.01				0.00
DW				1.98				2.00

Table 3: Output and price responses 1969-2005, monetary policy shocks calculated from a single monetary policy function spanning the whole period 1969-2005.

	Output response (Δy)				Price response (Δp)			
	Change in Output		Monetary Policy Shock		Change in Price		Monetary Policy Shock	
lag	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.	coeff.	s.e.
1	0.018	0.065	0.004	0.002	0.331	0.065	-0.000	0.001
2	0.194	0.065	-0.000	0.002	-0.208	0.070	-0.001	0.001
3	0.259	0.066	-0.002	0.002	0.100	0.071	-0.001	0.001
4	-0.053	0.068	-0.002	0.002	-0.029	0.071	-0.000	0.001
5	-0.054	0.068	-0.003	0.002	0.113	0.071	-0.000	0.001
6	-0.108	0.067	0.003	0.002	0.060	0.071	-0.002	0.001
7	0.029	0.067	0.002	0.002	0.124	0.071	-0.000	0.001
8	0.070	0.067	0.001	0.002	-0.013	0.071	- 0.000	0.001
9	0.088	0.067	-0.001	0.002	0.055	0.071	0.000	0.001
10	-0.070	0.066	-0.001	0.002	0.120	0.071	- 0.000	0.001
11	-0.005	0.064	-0.002	0.002	0.056	0.072	-0.002	0.001
12	0.296	0.065	-0.002	0.002	0.141	0.071	0.001	0.001
13	-0.023	0.064	0.000	0.002	-0.174	0.071	0.002	0.001
14	-0.154	0.064	0.002	0.002	0.069	0.072	0.001	0.001
15	-0.205	0.063	0.001	0.002	-0.134	0.072	0.001	0.001
16	-0.110	0.062	0.003	0.002	0.073	0.073	0.000	0.001
17	0.095	0.061	-0.001	0.002	-0.066	0.073	-0.001	0.001
18	0.147	0.061	-0.003	0.002	0.109	0.072	0.000	0.001
19	-0.069	0.061	0.003	0.002	-0.033	0.072	0.001	0.001
20	-0.093	0.061	0.003	0.002	-0.060	0.072	0.000	0.001
21	-0.066	0.061	0.001	0.002	0.192	0.073	0.000	0.001
22	0.034	0.060	-0.004	0.002	-0.152	0.074	- 0.000	0.001
23	-0.012	0.059	0.004	0.002	-0.037	0.074	-0.001	0.001
24	0.101	0.059	-0.000	0.002	0.074	0.069	-0.000	0.001
25			0.002	0.002			0.001	0.001
26			0.001	0.002			-0.002	0.001
27			-0.001	0.002			- 0.000	0.001
28			0.003	0.002			-0.002	0.001
29			-0.002	0.002			-0.001	0.001
30			0.001	0.002			-0.001	0.001
31			-0.000	0.002			-0.001	0.001
32			0.001	0.002			-0.000	0.001
33			-0.003	0.002			-0.000	0.001
34			0.004	0.002			-0.001	0.001
35			-0.002	0.002			0.000	0.001
36			0.001	0.002			-0.000	0.001
37							-0.001	0.001
38							-0.000	0.001
39							-0.001	0.001
40							-0.001	0.001
41							0.001	0.001
42							-0.001	0.001
43							-0.001	0.001
44							0.000	0.001
45							-0.001	0.001
46							0.000	0.001
47							0.001	0.001
48							-0.000	0.001
n				317				317
R^2				0.89				0.50
s.e.e.				0.01				0.00
DW				1.92				2.00

Table 4: Output and price responses 1979-2005, monetary policy shocks computed from a separate policy function spanning 1979-2005.