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**The Joint Dynamics of Inflation, Unemployment and
Interest Rate in the United States Since 1980**

by

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Abstract. In this paper, by using a combination of long-run and short-run restrictions, we identify a small structural VECM which includes inflation, unemployment and the federal funds rate and study the dynamic interactions at different frequencies among these variables. Our results show that: (i) in accordance with the traditional view of economic fluctuations, aggregate demand shocks and monetary policy shocks push inflation and unemployment in opposite directions in the short run; (ii) the permanent supply shock explains the long-run movement of inflation and unemployment. These conclusions are at odds with the prediction of “natural-rate” models but are consistent with the idea of a propagation mechanism which links productivity shocks to inflation and unemployment at medium and low frequencies. Thus, with respect to some recent studies (e.g. Beyer and Farmer, 2002 and Ireland, 1999), we offer a different interpretation of the low-frequency comovements between inflation and unemployment characterizing the US economy in the last decades.

Keywords: Structural VAR; Cointegration; Inflation; Unemployment

JEL classification: C32; E32; E31

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1. Introduction

According to traditional macroeconomic theory, the tradeoff between inflation and unemployment is a corner-stone of business cycle analysis. The existence of a negative short-run relationship between inflation and unemployment is also predicted by “natural-rate” theories, according to which monetary policy might provoke a change in cyclical unemployment in the presence of errors concerning the expected rate of inflation. Yet, “natural-rate” models predict long-run independence between inflation and unemployment.

Nevertheless, a different story seems to emerge from the recent experience of the US economy, since a falling rate of inflation coexisted in the 1990s with a simultaneous decline in the rate of unemployment. Note that a similar but symmetrical situation was experienced in the 1970s, when a sequence of adverse supply shocks produced an increase both in the rate of inflation and in the unemployment rate. Thus, starting from the observation that in the last 30 years the US economy has been characterized by low-frequency comovements of these variables, a recent strand of the research has investigated the possible existence of a long-run relation. Beyer and Farmer (2002), by using cointegration techniques, identify a long-run upward sloping Phillips curve and, as a consequence, pose some “natural rate doubts”. They interpret this result as due to the presence of a unit root in the shock to the aggregate demand equation. The existence of a positive long-run relation between inflation and unemployment has also been suggested by Ireland (1999), whose interpretation is based on a Barro-Gordon type model in which the unit root in the natural rate of unemployment is translated into the rate of inflation for the inability of the central bank to commit to a credible low-inflation policy.

In our opinion, these two alternative explanations of the low-frequency comovements of inflation and unemployment are unsatisfactory. As for Ireland’s explanation, Beyer and Farmer show that it rests on the existence of a Fisher relation between inflation and nominal interest rate but, in fact, this assumption is strongly rejected by data¹. We believe that another important shortcoming derives from the consideration that the period covered by Ireland’s investigation, i.e. 1970-1999, is characterized by different monetary policy regimes. Whatever the assessment regarding the conduction of monetary policy in the 1970s, it is hardly credible that during the Volker-Greenspan era the central bank has

¹ Indeed, Ireland (1999) estimates a bivariate VAR model including inflation rate and unemployment. Beyer and Farmer (2002) include also the short-term nominal interest rate and investigate low-frequency relations between inflation and interest rate.

undertaken opportunistic policies which aimed to exploit the short-run tradeoff.

As far as Beyer and Farmer's explanation is concerned, it exhibits a fundamental weakness: in the presence of persistent demand shocks, i.e. their key assumption, we expect to observe movements in opposite directions between inflation and unemployment at low frequencies. But, in fact, in the US economy we observe a movement of the two variables in the same direction.

In this paper we take a different view. We investigate the dynamic relationships at different frequencies among inflation, unemployment and federal funds rate since 1980 in the United States by estimating a cointegrated VAR model on which is imposed the restriction of persistent shocks on the supply side.

King et al. (1991) pioneered the use of structural VARs, based on restrictions at zero frequencies, in the context of cointegrated systems. In this paper we identify the permanent shock by imposing a set of long-run restrictions which rest on the assumption of a unit root in the shock to the aggregate supply equation. The complete identification of the structural model is achieved by imposing that the transitory, monetary policy shock, does not exert a contemporaneous effect on the rate of unemployment. Our main conclusions are: (i) the existence of a short-run tradeoff is confirmed by data, i.e. as a consequence of monetary policy shocks and other aggregate demand shocks inflation and unemployment are pushed in opposite directions; (ii) as expected, aggregate demand shocks play a dominant role at the business cycle frequencies; (iii) nevertheless a permanent supply shock explains the long-run movement of the series. An important role is also played by the supply shock in explaining the variability of unemployment at medium frequencies. These conclusions contrast with models that predict long-run monetary superneutrality but are consistent with the idea of a propagation mechanism which links productivity shocks to inflation and unemployment at medium and low frequencies.

An explanation along these lines of the recent evolution of the US economy is given in Ball and Mankiw (2002). The authors maintain that although the simultaneous fall of inflation and unemployment in the second half of the 1990s is open to different interpretations, the observed link between the fluctuations in the NAIRU (non-accelerating inflation rate of unemployment) and the fluctuations in productivity growth deserves further analysis since it appears a particularly promising line of investigation. It is worth pointing out that this link was first suggested by Grubb et al. (1982) who proposed a model which aimed to explain the observed correlation among the productivity slowdown and the increase in both inflation and unemployment characterizing the 1970s.

The paper is organized as follows. In section 2 we conduct an empirical investigation covering the period 1980:1-2001:12 by using a cointegrated VAR

model. In this context we identify two long-run relations. Section 3 is devoted to identification of structural disturbances. In section 4 we present the impulse-response functions and the forecast-error variance analysis. Section 5 concludes.

2. Estimation

Let us consider a vector X_t (3×1) of I(1) series, where $X_t = [\pi_t, u_t, i_t]'$. We utilize monthly data² covering the period 1980:1-2001:12. Moreover, π is the annualized rate of inflation³ measured by the consumer price index, u is the civilian unemployment rate and i is the federal funds rate. We take the three series as I(1) processes⁴. As for lag length selection, both the Hannan-Quinn and the Schwarz criterion suggest 5 lags for the estimated VAR.

We start the empirical analysis by estimating the following reduced form:

$$\Gamma(L)\Delta X_t = \mu - \gamma\alpha'X_{t-1} + \epsilon_t \quad (1)$$

where ϵ_t is the (3×1) vector of disturbances such that $E(\epsilon_t) = 0$ and $E(\epsilon_t\epsilon_t') = \Omega_\epsilon$. Δ is the difference operator, L is the lag operator and μ is a constant vector. In general, considering a n -dimensional dynamic linear system, the rank, $r < n$, of the autoregressive total multipliers matrix $A(1) = \gamma\alpha'$, is given by the number of independent long-run relations. Moreover, γ is a ($n \times r$) matrix of loadings and α is a ($n \times r$) matrix of cointegrating vectors. It is well known that it is possible to offer a structural interpretation of these relations only by imposing some meaningful identifying restrictions, since for any non-singular $n \times n$ matrix, Q , such that $\gamma_0 = \gamma Q^{-1}$ and $\alpha'_0 = Q\alpha'$, we obtain $A(1) = \gamma\alpha' = \gamma_0\alpha'_0$. It is shown that exact identification of the cointegrating vectors is achieved by imposing r normalizations, one for each vector, and $r - 1$ restrictions for each row, i.e. a total of r^2 independent restrictions⁵(see, e.g. Johansen, 1995).

² The series are taken from FRED at the St.Louis FED Web site.

³ We take the average value of inflation over the last four months.

⁴ The usual battery of unit roots tests has been conducted (both univariate and multivariate tests) and the results do not reject the hypothesis that the series can be represented as difference-stationary processes. The unit root properties of these series are investigated, among others, in Beyer and Farmer (2002). The authors conclude that all the three processes seem to exhibit a unit root. Nevertheless, it is well known that, given finite samples, it is not possible to discriminate between "persistent processes" and "unit root processes" in the sense that unit root tests suffer from arbitrary low power as against a sufficiently close alternative

⁵ By considering the equation $A(1) = \gamma_0\alpha'_0$, it is easily checked that in order to achieve

As shown in table 1, on the basis of Johansen's (1992) trace test, at the 10 per cent level, it is possible to select a cointegration rank of two.

Insert Table 1 about here

In a first stage, we impose the following exactly identified long-run structure:

$$\alpha'_0 X = \begin{pmatrix} 1 & \alpha_{12} & 0 \\ 1 & 0 & \alpha_{23} \end{pmatrix} \begin{pmatrix} \pi \\ u \\ i \end{pmatrix} \quad (2)$$

Hence, we investigate a possible long-run relationship between inflation and unemployment and the existence of a long-run relation between inflation and federal funds rate. In a second stage, we test the hypothesis (see table 1) that the cointegration space contains: (i) a long-run Fisher relation, i.e. a one-for-one movement at very low frequencies between inflation and nominal interest rate; (ii) a one-for-one movement between inflation and unemployment in the long run. Given the estimated coefficients and the associated standard errors, the Fisher hypothesis is strongly rejected by data⁶. Instead, as far as the first relation is concerned, we conclude that it is not possible to reject the hypothesis that in the long run inflation and unemployment move one-for-one in the same direction.

Johansen (1991) has shown that the reduced-form Wold representation of (1) is given by:

$$\Delta X_t = \rho + B(L)\epsilon_t \quad (3)$$

long-run identification it would be possible to follow an alternative strategy based on imposing restrictions on the matrix of error-correction coefficients.

⁶ This is the same conclusion reached by Beyer and Farmer (2002) for the period 1971-1999. Of course, the literature on the subject does not reach a common conclusion since, as usual, the results are sensitive to the sample spanned and to the strategy of estimation followed by researchers. For instance, Crowder et al. (1999) estimate a cointegrated VAR model which covers the postwar period (1954-1996) and includes four variables: real money balances, inflation, real income and the monthly commercial paper rate. The authors assume that the ex post inflation rate is a good indicator of expected inflation and find evidence in favour of the Fisher hypothesis.

where: (i) $\rho = B(1)\mu$; (ii) $B(1) = \alpha_{\perp}\Phi\gamma'_{\perp}$. γ_{\perp} e α_{\perp} are, respectively, the orthogonal complements to the matrix of error correction coefficients and the matrix of cointegration vectors, i.e. $\alpha'\alpha_{\perp} = 0$, $\gamma'\gamma_{\perp} = 0$; (iii) $\Phi = (\gamma'_{\perp}\Psi\alpha_{\perp})^{-1}$, where Ψ is the derivative of $\Psi(z)$, the characteristic polynomial of model (1), for $z = 1$.

3. Identification of Structural Disturbances

The results concerning the cointegration analysis have shown low-frequency comovements between nominal and real variables which are at odds with the prediction of long-run separation of the classical monetary theory. Moreover, recall that since we detected the presence of two equilibrium long-run relations, we can always think of the dynamic system as if it were driven by a single permanent shock. Hence, a crucial question regards the identification of the common source of variability at frequency zero of inflation, unemployment and federal funds rate.

Grubb *et al.* (1982) proposed a framework aiming to explain the relationship, observed in the 1970s in many industrialized countries, among the productivity slowdown and the simultaneous increase in the rate of inflation and in the rate of unemployment. Their study pointed out that phases of economic development characterized by sudden change of pace of productivity growth may produce a discrepancy between the feasible real wage and workers' claims. The central assumption underlying the model is that, in general, workers have wage aspirations that are mainly based on past experience of wage growth rate. In turn, this is linked to the past growth of productivity. Hence, in the presence of a turning point in productivity, such as for example in the negative experience of the 1970s mainly provoked by the oil shocks, this link is broken since there is a slow adaptation of the workers' claims to the changed economic environment. In these historical contexts, productivity shocks may exert persistent effects on both inflation and unemployment.

In a recent paper, Ball and Mankiw (2002) argued that this model well fits some facts characterizing the US economy in the 1990s. For, the information-technology revolution induced an acceleration of productivity growth which was associated with a simultaneous decrease in both inflation and unemployment. Indeed, these facts, observed in the US economy, seem to suggest that the mechanism also works in opposite direction.

In this paper we adopt this framework as an organizing scheme in order to recover the structural disturbances and, in particular, in order to separate the permanent from the transitory shocks.

Thus, the structural Vector Moving Average representation is given by:

$$\Delta X_t = \rho + H(L)e_t \quad (4)$$

where: $H(L) = B(L)H(0)$, $e_t = H(0)^{-1}\epsilon_t$ and $E(e_t e_t') = I$. $e_t = (e_{1t}, e_{2t}, e_{3t})'$ is the (3x1) vector of structural disturbances. Since $H(0)$ satisfies $H(0)H(0)' = \Omega_\epsilon$ and given the symmetry of Ω_ϵ , this imposes six restrictions on the nine elements of $H(0)$ and hence three further restrictions are required in order to obtain exact identification. Given orthonormal innovations, we identify the structural disturbances by imposing: (i) that both, e_{2t} and e_{3t} , exert only transitory effects on the level of the three variables, i.e. that the source of low-frequency common movements of the variables is a unit root in the shock to the aggregate supply equation; (ii) that e_{3t} does not contemporaneously affect u_t .

Hence, the following two restrictions are imposed on the matrix of structural long-run multipliers: $H(1) = B(1)H(0) = \alpha_\perp \Phi \gamma_\perp' H(0)$, is such that the second and third column of $H(1)$ contain zero elements. This allows e_{1t} to be identified as the permanent supply shock. Finally, in order to achieve exact identification we impose a restriction on the contemporaneous effects of innovations.

Thus, we separately identify the demand shock and the monetary policy shock. Note that inflation and unemployment are allowed to have contemporaneous effects on the federal funds rate, whereas an unexpected change in the federal funds rate has the contemporary effect on the rate of unemployment restricted to zero.

A final important question arises from noticing that long-run relations also include the federal funds rate and, moreover, that an implication of our identification scheme is the permanent effect exerted on the federal funds rate by a supply shock. We pointed out that on the basis of the empirical analysis we rejected the Fisher hypothesis for the period under investigation. Since the Fisher hypothesis is clearly consistent with models which predict long-run separation between nominal and real variables, we find the results, as a whole, internally consistent. Nevertheless, we have to explain the mechanism through which a unit root in the supply equation is translated into a unit root in the federal funds rate. To this end, let us suppose that a productivity shock causes, under certain conditions, a permanent effect on the inflation rate, then if the central bank is committed to an anti-inflation policy this makes it possible a translation into a permanent effect on the federal funds rate.

Summing up: we investigate about a propagation mechanism, originating

from productivity shocks, that induces a persistent reaction of opposite sign in the federal funds rate due to persistent effects of this shock on inflation and unemployment. In turn, these effects on inflation and unemployment derive from the slow adaptation of workers' claims to the new pace of productivity growth⁷.

Note that we use a combination of short-run and long-run restrictions. Such a strategy has been adopted by, among others, Gali (1992) and, more recently, by Fisher, Huh and Summers (2000) who apply this procedure to the six-variable model of King, Plosser, Stock and Watson (1991)⁸ in order to identify the permanent shocks affecting the dynamic system.

In a recent study, Crowder, Hoffman and Rasche (1999) identified permanent and transitory shocks in a four-variable cointegrated model of the US economy in the postwar period. Moreover, in this study two long-run relations are also identified: an aggregate money demand equation and a Fisher relation. It is worth stressing that the authors identify two distinct permanent real and nominal shocks which drive the long-run behaviour of real and nominal variables, respectively.

4. The Dynamic Effects of Structural Disturbances

In this section we present the results attaining the dynamic responses of each variable (see Figure 1) to the identified structural shocks⁹ and use the Forecast Error Variance Decomposition analysis (FEVD) in order to investigate the relative importance of structural disturbances (see Figure 2) in explaining the variability of the series at different horizons¹⁰.

⁷ Note that we are reasoning about the identification of a sort of *causa causans*, but surely other factors (e.g. the role of increasing openness of the economy and demographic factors) have been at work in shaping the recent evolution of the unemployment rate in the US economy. A close evaluation of such other factors is given in Ball and Mankiw (2002).

⁸ The paper by King et al. (1991) extended the Blanchard-Quah (1989) model, based on long-run restrictions, to cointegrated systems. The strategy of identification followed by King et al. consists in: (a) utilizing the cointegration restrictions in order to identify the permanent shocks; (b) assuming the innovations in the permanent components uncorrelated with the innovations in the transitory components and then investigating the dynamic effects on economic variables of the permanent innovations. A recent survey of methods that identify permanent and transitory shocks in cointegrated systems is provided by Levchenkova, Pagan and Robertson (1998).

⁹ We plot the impulse-response functions with the 90 per cent confidence bounds which are obtained by following the analytical formulae presented in Amisano and Giannini (1997).

¹⁰ By definition, at each horizon and for each variable the FEVD parameters sum up to unity.

Insert Figure 1 about here

Let us note the particular role played by the permanent shock. As a consequence of a (negative) supply shock the inflation rate increases. For about two years there is no significant reaction in the unemployment rate, but thereafter there is an increase which turns out to be permanent. There is also a permanent increase in the federal funds rate and it is worth noticing that this adverse productivity shock has a significant contemporaneous effect on the interest rate.

An aggregate demand shock which induces a fall in inflation, causes an increase in the rate of unemployment. It takes about two years for these effects to vanish. Thus, we observe the typical movements in opposite directions between inflation and unemployment at business cycle frequencies. As for the federal funds rate, we observe a fall as a consequence of the negative demand shock.

It is important to stress the different behaviour of the short-term interest rate in the presence, respectively, of supply and demand shocks: when the increase in the rate of unemployment is due to movements on the supply side which in turn cause an increase in the inflation rate, the federal funds rate moves towards a higher level; on the other side, when the increase in the unemployment is caused by negative movements of aggregate demand, which in turn cause a decrease in the inflation rate, the federal funds rate temporarily moves towards a lower level, thus helping the stabilization of the economic system.

In our opinion this shape of the impulse-response functions clearly contrasts with the idea maintained by Ireland (1999), according to which the central bank in the 1970s and 1980s was unable to commit to a credible low-inflation policy and aimed at contrasting an increase in the natural-rate of unemployment with expansionary policies.

An unexpected movement in the federal funds rate sparks off a disinflationary process which lasts for about three years. Although there is little reaction of unemployment for about twelve months, the disinflationary process is characterized by an increase in the unemployment rate at business cycle frequencies. Hence, our results confirm the widely held view that monetary policy pushes inflation and unemployment in opposite directions in the short run¹¹.

Note that our identification scheme does not generate a price puzzle, i.e. in response to a restrictive monetary policy shock, CPI inflation does not move

¹¹ Indeed, we observed such a tradeoff also in the last recession experienced by the US economy: the rate of unemployment was 3.9 percent in August 2000 and the rate of inflation about 3 percent; at the end of 2001 the unemployment rate was about 6 percent whereas inflation had reduced to 2 percent. A recent assessment on theory and empirics concerning the short-run tradeoff between inflation and unemployment is given in Mankiw (2001).

up but, instead, exhibits the sign predicted by the conventional view about the effects of monetary policy¹².

It is important to point out that both the demand shocks and the monetary policy shocks do not exert very persistent effects on inflation and unemployment. Recall that we imposed a mixture of contemporary and long-run restrictions, but the dynamic effects of structural disturbances at other frequencies are not restricted. Hence, we do not find much support for the thesis of Beyer and Farmer (2002) that demand shocks are the source of low-frequency comovements of inflation and unemployment.

As shown in figure 2, supply shocks account for the major part of inflation variability at all frequencies. This is quite a surprising result in the light of the pre-eminent role usually attributed to shocks on the demand side. Note that both the demand shock and the monetary policy shock account for a small portion of variability at all frequencies.

Insert Figure 2 about here

As for unemployment, we find that the demand shock plays a dominant role at business cycle frequencies. For about three years the supply shock has almost no importance in composing the forecast-error variance of unemployment, but thereafter there is an increasing role, in a parallel direction with the declining importance of the demand shock. It is worth noticing the negligible contribution of the monetary policy shock in accounting for the variability of unemployment.

Indeed, an important point emphasized by some studies (e.g. Christiano *et al.*, 1999) is that attributing a small part of variation in inflation and unemployment to monetary policy shocks, i.e. attributing a limited role to monetary policy shocks in business cycle fluctuations, does not amount to concluding that a limited role is also played by the systematic component of monetary policy in explaining the evolution of inflation and unemployment at business cycle frequencies.

As far as the federal funds rate is concerned, the supply shock explains about

¹² In order to avoid the price puzzle, it has become common practice, following a suggestion by Sims (1992), to include in the information set of the policy makers present and past values of the commodity price index, interpreted as a leading indicator of future inflation. A survey of studies on the application of VARs to monetary policy is provided by Christiano *et. al.* (1999). An alternative approach, recently proposed by Uhlig, consists in taking the traditional view as given and then imposing sign restrictions on the impulse response functions. For instance, in Uhlig (2001) a crucial restriction which is imposed on the response of prices is that CPI inflation does not rise above zero in the first year following the monetary policy shock.

50 percent of the variability at high and medium frequencies whereas a minor role is attributed to the aggregate demand shock. We believe this represents further evidence that, in the period under investigation, the central bank was mainly concerned in the period under investigation with the control of inflation.

5. Conclusions

There are two stylized facts which seem to characterize the US economy in recent decades: (i) when the economic system experiences recessions, such as in the period 1980-1982, or in the current crisis, inflation and unemployment move in opposite directions; (ii) at low frequencies they exhibit positive comovement.

The main aim of this paper was to provide a structural interpretation of these facts. In particular, we estimated a small cointegrated structural VAR model in order to investigate the role played by permanent productivity shocks in explaining the movement at different frequencies of inflation, unemployment and short-term interest rate in the US economy in the last 20 years. Our results show that the simultaneous fall in inflation and unemployment experienced in recent years is consistent with a story in which the causal link goes from positive shock to productivity to reduction in the rate of growth of prices and in the rate of unemployment. A possible explanation of the propagation mechanism rests on a slow adjustment of workers' claims to changed productivity growth. This scheme was proposed by Grubb et al. (1982) as an interpretative framework of the slowdown which was experienced in the 1970s by industrialized countries and that witnessed a simultaneous rise in inflation and unemployment.

We have also identified two transitory shocks which are interpretable, respectively, as aggregate demand shocks and monetary policy shocks. As suggested by traditional interpretations of the business cycle, both the transitory shocks push inflation and unemployment in opposite directions in the short run. Yet, it is worth noticing that these shocks produce significant effects for about two-three years and hence we do not detect persistent effects on the demand side. Moreover, the relative contribution of the monetary policy shock to the variability of unemployment at different horizons appears small.

As for the supply shock, an interesting result is that not only does it account for the variability of the series at low frequencies but it also plays an important role in explaining the variability of inflation, unemployment and federal funds rate at medium frequencies.

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TABLE 1
Cointegration Analysis

Hypothesis	$r = 0$	$r \leq 1$	$r \leq 2$
Trace statistic			
Observed value	58.86	15.15	2.06
90% critical value	26.79	13.33	2.69
Variable	π	u	i
Cointegrating Vectors:	1.0	-1.065 (0.27)	0
exactly identified structure	1.0	0	-0.467 (.06)
H_0 : The Cointegration space contains			
long-run Fisher relation	1.0	-0.331(0.22)	0
	1.0	0	-1.0
$\chi^2(1) = 8.33$			
p-value 0.004			
one-for-one long-run relation between π e u	1.0	-1.0	0
	1.0	0	-0.462 (.06)
$\chi^2(1) = 0.03$			
p-value 0.864			

Notes: Results for the period 1980:1 2001:12 are based on a reduced form model which includes CPI inflation, unemployment rate and federal funds rate. The numbers in parentheses are standard errors. Johansen's likelihood ratio test of restrictions on the cointegrating vectors is distributed as a chi-squared with degrees of freedom equal to the number of restrictions tested.

Figure 1. Impulse Responses

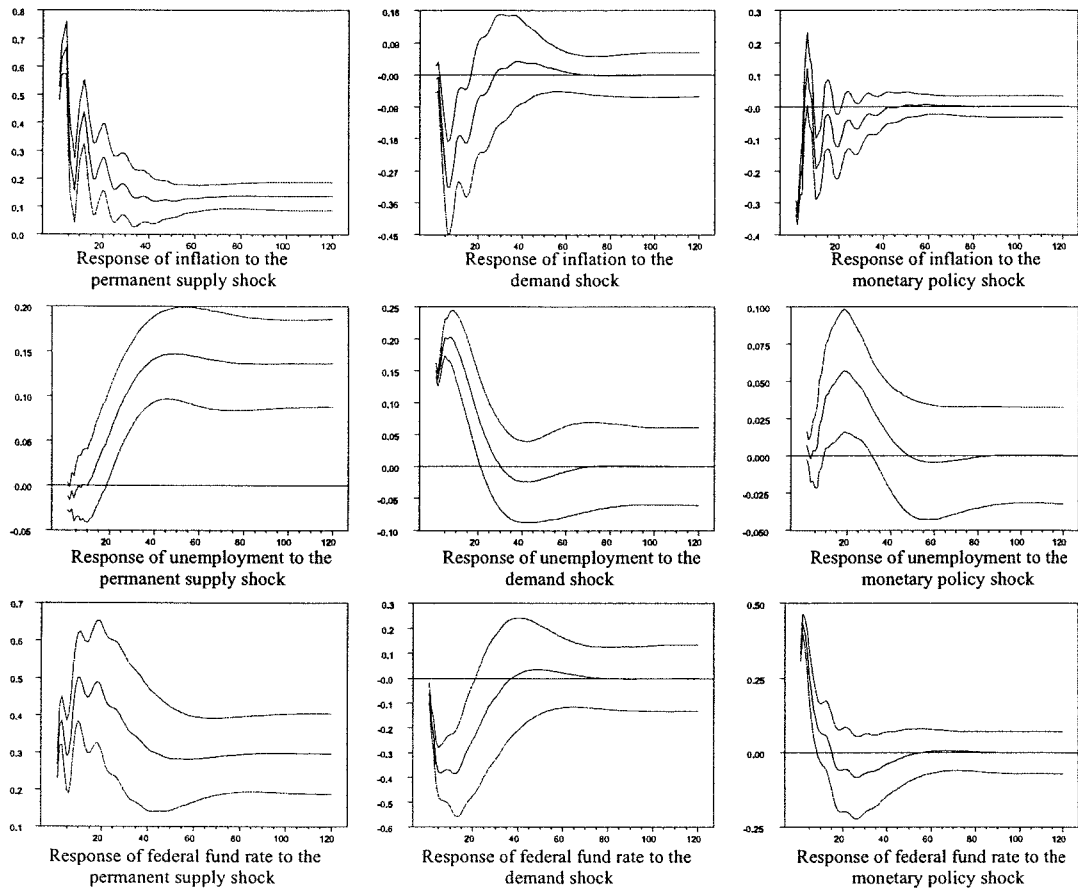
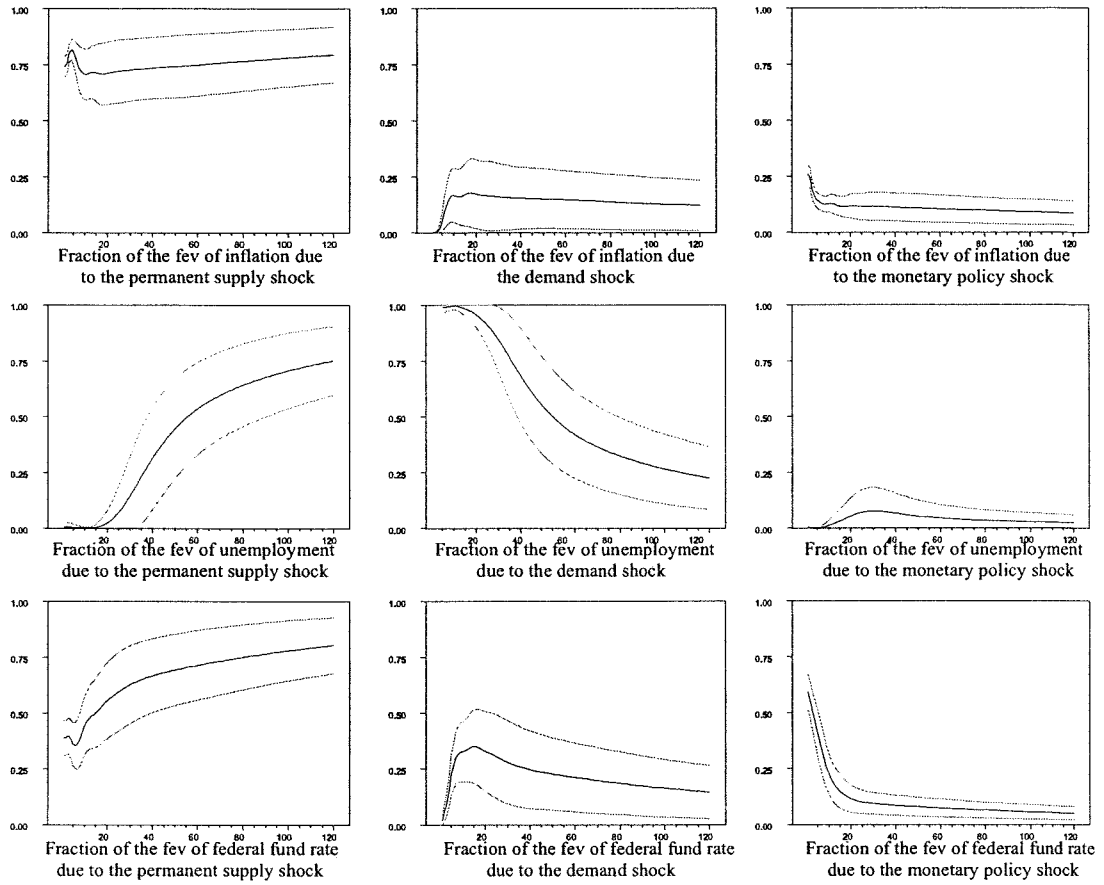


Figure 2. Decomposition of Forecast-Error Variance (FEV)



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