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"Output, Inflation, and Stabilization in a Small Open Economy: Evidence From Mexico"

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"Output, Inflation, and Stabilization in a Small Open Economy: Evidence From Mexico"

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Abstract

The sources of fluctuation in output and two views of the causes of high inflation (fiscal and balance-of-payments views) are examined in an estimated structural vector autoregression for Mexico. Movements in output and inflation are driven by fiscal, real, money growth, exchange rate, and asset market disturbances, identified using an estimatable equilibrium model incorporating important features of high inflation economies. We find that changes in inflation are influenced by all shocks, while output growth is explained by real, fiscal, and asset shocks. The results lend support to both the fiscal and balance of payments views of inflation, and contain evidence that higher inflation and higher budget deficits cause each other to spiral upward.

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I. Introduction

Understanding the sources of fluctuations in output and inflation is as important a challenge to empirical macroeconomists as any issue. A long-standing issue in academic and policymaking circles is whether or not stabilization without recession is possible. Some theoretical models suggest that such a favorable outcome is possible for high inflation countries, although it requires credible, "shock treatment" approaches to disinflation. There is a lot of evidence indicating that even if stabilization without recession is achievable in principle, it is difficult in fact.

Two prominent views of inflation in small and open, high-inflation economies go a step back from the old adage that the root of inflation is always monetary. First, there is a widely-held "fiscal view" of inflation which asserts that budget deficits are a fundamental cause of inflation in countries with prolonged high inflation. In its most basic guise, the view is that deficit finance is inflationary because it is accompanied by base money creation rather than debt. Many also posit a channel of causation that runs from inflation to deficits - high inflation worsens the fiscal deficit because it creates the incentive for private agents to delay paying taxes as long as possible, so that the real value of the obligation is eroded [Tanzi (1977)]. This can send the inflation rate on an upward spiral.

Second, the "balance of payments view" of inflation, which is relevant especially for small open economies, emphasizes the exchange rate. According to this view, exchange rate collapses, prompted by balance of payments crises, bring about inflation either through higher import prices, increases in inflationary expectations which are then accommodated, or a sped-up wage indexation mechanism. Budget deficits are related only because they deplete foreign reserves, which prompts a balance of payments crisis, exchange rate collapse, and higher inflation via the mechanisms above.[1]

[1] For an expanded treatment of the issues addressed above, see Sargent (1980), Sargent and Wallace (1981), Garber (1982), Dornbusch and Fischer (1986), and Bruno, et. al. (1987).

Systematic econometric studies of movements in output and inflation, and their dynamic interactions, in high-inflation countries are often difficult to conduct in part because of poor time-series data. In this paper we undertake such a study with Mexican data - the most feasible among several possible candidates.[2] We estimate an equilibrium model for a small open economy, in which movements in inflation and output are driven by several fundamental disturbances - fiscal, real, monetary, exchange rate, and asset - which are identified using restrictions based on a plausible illustrative model, derived to reflect important features of a small and open, high-inflation economy. Our analysis of the endogenous response of output and inflation to the shocks suggests that own shocks, fiscal shocks, and asset shocks have important influences on output growth, while fiscal shocks, money growth shocks, and "external" shocks are nearly equally influential for inflation. We also find evidence that higher inflation and budget deficits can cause each other to spiral upward.

II. Mexican Macroeconomic Performance

In this section we describe Mexico's experience with high inflation since 1972.[3] Inflation rose above single-digit annual levels in 1973 for the first time in twenty years. This coincided with aggressive public sector policies of expenditure-led growth and income redistribution under the statist administration of President Luis Echeverria. Increases in government spending caused the public sector deficit to balloon from 2.5 percent of GDP in 1971 to 10 percent in 1975. These deficits were largely financed by the central bank (the monetary base grew by 19.6 percent in 1971 but 33.8

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[2]Feasible in the sense that (1) data on government spending and taxes are readily available, which is essential to test the "fiscal view", and (2) the data are available monthly over a fairly long period of time, to provide enough observations as required by our econometric technique. Data from other Latin American countries or Israel, for example, do not possess these features.

[3]This episode is treated in Bruno, Di Tella, Dornbusch, and Fischer (1987) and Buffie (1990). Mexican inflation never reached the heights of Argentine or Brazilian inflation, but it has been worrisome. Our empirical analysis begins in 1977 due to data availability. The following description is important for justifying the split dates chosen in the diagnostic analysis of section V.

percent in 1975), although foreign borrowing soon became an additional source. An exchange rate of 12.5 pesos to the dollar was maintained (until August 1976) amidst three and one-half years of 20 percent annual inflation rates. Overvaluation combined with rising fiscal deficits to produce a deterioration in the balance of payments and a capital flight which became acute in mid-1976. With the central bank's stock of foreign reserves nearly depleted, the peso was devalued by almost 100 percent on August 31, 1976. A period of economic turmoil ensued, as Echeverria handed over the presidency to Lopez Portillo.

An agreement with the IMF on a stabilization program was reached in September 1976. The program was mildly successful in 1977, as the public sector deficit was reduced from 10 to under 7 percent of GDP, and annual inflation fell from 27 to 20 percent. However, the growth rate of real GDP fell for the fourth consecutive year in 1977 to 3.4 percent, from 4.2 percent in 1976. In 1978 the IMF program was scrapped in favor of a return to policies designed to promote growth through public-sector expenditure. The switch was directly the result of the discovery of enormous oil wealth in 1977, and the consequent loosening of the foreign borrowing constraint.

In large part because of the oil discovery, economic performance between 1978 and 1981 was impressive: annual GDP growth was never less than 8 percent, while the inflation rate stayed in the range of 20 percent. However, it became apparent that the policies of the Echeverria administration were being repeated, now on a larger scale. Public sector expenditure increased in real terms by 97.7 percent from 1977 to 1981, rising from 29.5 percent of GDP to 41.3 percent. The budget deficit grew from 6.7 to 14.7 percent of GDP during this period, because failure to maintain public sector prices in real terms prevented a significant rise in tax revenue. The exchange rate, which was ostensibly flexible, rose at an average annual rate of only 3.6 percent during these years. The budget deficit and real appreciation led to a rise in the volume of imported intermediate inputs of 128 percent. This coincided with higher output and employment, but eventually was accompanied by a resurgence of inflation, unsustainable balance of payments deficits, and a burdensome foreign debt.

Failed attempts at adjustment in late 1981 and early 1982, amid several signs of serious economic problems, reflected the weakness of Lopez Portillo's economic policymaking. A 67 percent devaluation in February 1982, new external loans, planned cuts in public spending and increases in public sector prices did not stop the flight out of peso-denominated assets and Mexdollars. The crisis unfolded in August 1982 with a devaluation of nearly 100 percent, the introduction of a dual exchange rate system, price hikes on staples, and a forced conversion of Mexdollars into pesos. These were followed by the nationalization of the banks in September and a moratorium on foreign debt payments until a rescheduling agreement was reached in December 1982. In 1982 inflation reached 100 percent, while real GDP growth was negative for the first time in 50 years.

President De La Madrid's administration began in 1983 with a wide-ranging program of stabilization and reform, along with negotiations over the foreign debt. Fiscal austerity, lower money growth rates and improvement on the external accounts were prominent goals of the program, just as in 1976. During this time Mexico achieved much success in meeting its targets. From 1982 to 1983, the public sector deficit was halved - to 8.9 percent of GDP, money growth rates declined in both real and nominal terms, and the current account balance went from a 6 billion dollar deficit to a 5 billion dollar surplus in large part due to tight controls on imports.

Success in meeting the targets initially was accompanied by a deep recession - real GDP growth was -5.3 percent in 1983 - with only a slight drop in inflation to 80 percent. Furthermore, the effects of import compression and deep cuts in capital expenditures on long-term growth prospects were disconcerting. In 1984 and early 1985, real GDP growth improved modestly, inflation fell into the 60 percent range, and the current account remained in surplus. At the same time, the budget deficit began to rise slightly, and plans for a fiscal correction were announced in March 1985.

Money growth was strictly controlled in spite of the fiscal deficits, which were financed by sales of government bonds (CETES) to the banking system and public.

In the second half of 1985 the economy slipped back into recession, as world oil prices fell, a devastating earthquake hit Mexico City, and a tight money policy was followed. Oil prices continued to fall in 1986 and the public sector deficit rose to 16.3 percent of GDP. De La Madrid's program of monetary and fiscal contraction was continued, and an increase in the rate of peso depreciation was implemented to cushion the blow to the balance of payments from falling oil prices. At the time, Mexico faced stagflation - real GDP growth was negative 3.8 percent and the rate of inflation reached 106 percent in 1986. The economy's performance in 1987 was no better: although real GDP growth was positive, inflation rose to 160 percent.

Stabilization succeeded after 1988, as real growth resumed and inflation subsided. The administration of President Salinas has symbolized a new beginning for economic policymaking in Mexico. The administration's continuation of trade liberalization and normalizing relations with creditors has produced benefits. Mexico was the first country to participate in the Brady plan for debt restructuring, and the North American Free-trade Agreement is about to be completed. The rate of inflation has fallen steadily to twenty percent, and real output growth has improved.

III. Derivation and Estimation of the Model

First, we describe the econometric methodolgy used. Then we develop a model of a small, open economy which explicitly identifies the shocks that could be the main sources of fluctuations in output and inflation. We assess the significance of those shocks on output and inflation using impulse response functions and variance decompositions. We identify five shocks: fiscal, real, money growth, exchange rate, and asset shocks.

Methodology

We are interested in the following structural model,

$$\underline{x}_t = \underline{k} + C\underline{x}_t + G_1\underline{x}_{t-1} + \ldots + G_p\underline{x}_{t-p} + \underline{\varepsilon}_t,$$

where $\underline{x}$ is a vector of time-series variables, $\underline{k}$ a vector of constants, and $\underline{\varepsilon}_t$ is a vector of structural disturbances, which we refer to as "shocks". The individual elements of $\underline{\varepsilon}_t$ are uncorrelated, so that the covariance matrix is diagonal. With non-zero off-diagonal elements in the matrix C, one or more of these shocks may influence any particular variable. The reduced form of this model is an unrestricted VAR,

$$\underline{x}_t = \underline{K} + A_1\underline{x}_{t-1} + \ldots + A_p\underline{x}_{t-p} + \underline{v}_t,$$

where $\underline{K}$ is a vector of constants, $A_i = (I-C)^{-1}G_i$, and $\underline{v}_t = (I-C)^{-1}\underline{\varepsilon}_t$ is a vector of residuals - referred to as "innovations" - with covariance matrix S. The contemporaneous correlation between the innovations is justified in the model below. The illustrative model is to be interpreted as providing a rationale for the short-run restrictions used to identify the VAR.

The estimation technique involves first estimating the unrestricted VAR; estimates of the first-step innovations are obtained from this. The model is identified by postulating a structure for C, and is estimated using the method of moments [see Bernanke (1986)]. Specifically, consider

$$\hat{S} = (I - \hat{C})M(I - \hat{C})'$$

where $M = (\Sigma v_t v_t')/T$ is the sample covariance matrix of the first-stage residuals. The estimator selects elements of C such that the estimated covariance matrix of fundamental shocks, S, is diagonal (which is implied by the assumption that the shocks are fundamental). There are $n(n+1)/2$ distinct elements of the symmetric matrix M. With n equation variances to estimate, in a just-identified system $n(n-1)/2$ non-zero elements of the C matrix may be estimated. As seen in the next section, where we specify **C**, we depart from the "atheoretical" methodology - in which a lower-triangular structure is imposed on **C**.[4]

Orthogonalization

We derive the restrictions used to identify the VAR with the following illustrative model. Because the estimation method requires only restrictions on the contemporaneous correlations between variables, we omit any lagged terms in all of the structural equations below. The economy contains four sectors - goods, government, money, and external - which we analyze in turn.

The organizing principle for the model is a modified dynamic aggregate demand-aggregate supply framework. There are two fundamental markets in our economy: goods and money (by Walras' law, the bond market can be omitted). Goods market equilibrium is specified with emphasis on the role of government, while money market equilibrium is characterized by generalizing the traditional LM relationship in such a way to account explicitly for the feedback effects of macroeconomic disturbances on the money supply rule. External factors can affect the domestic economy through their influences on the nominal interest rate and their direct effect on real balances. The former effect is based on uncovered interest rate parity and the latter is based on purchasing power parity, each of which holds up to an error term as described below. Aside from the Phillips

[4]Note that in any model it is likely that the elements of the vector $\underline{v}$ (the first-stage VAR residuals) are contemporaneously correlated, so that $E(\underline{v}\underline{v}') = \mathbf{M}$ is not diagonal. It is more appropriate to work with orthogonalized innovations, however, so it is common to transform the first-stage innovations. Under the atheoretical approach, the Choleski decomposition is used. This procedure selects a lower-triangular matrix **J** such that $\mathbf{J}\mathbf{J}' = \mathbf{M}$. Then because $\mathbf{J}^{-1}\mathbf{M}\mathbf{J}'^{-1} = \mathbf{I}$, replacing $\underline{v}$ by $\mathbf{J}^{-1}\underline{v} = \underline{u}$, the vector of variables $\underline{x}$ can be written in terms of the $\underline{u}$, which by construction are uncorrelated across equations and across time. A major criticism of this approach stems from the fact that these decompositions are not unique. Under Bernanke's methodology, the decomposition matrix $\mathbf{F} = (\mathbf{I} - \mathbf{C})^{-1}\mathbf{S}^{1/2}$ is chosen such that $\mathbf{F}\mathbf{F}' = \mathbf{M}$, where **S** is the diagonal covariance matrix of the fundamental disturbances. Thus **F**, which need not be lower-triangular, provides a decomposition matrix that is based on a structural model. See Bernanke (1986) or Blanchard (1989) for more discussion of the estimation technique, and Cooley and LeRoy (1985) for criticism of the atheoretical approach.

curve relationship, the interactions between goods and money markets are mainly driven by inflationary finance and the Tanzi (1977) effect.

Let p and y represent the logs of prices and output, and define the inflation rate from period t-1 to t as $\pi_t = \Delta p_t$. Within our framework, the inflation rate can be affected by changes originating in both goods and money markets. Specifically, inflation is assumed to be related to its own lagged value (with a unit coefficient),[5] and to contemporaneous shocks to government spending, output, and money growth. Thus, normalizing in units of the money growth shock, we have,

$$(1') \qquad \Delta\pi_t = \hat{\pi} + \alpha_1\epsilon_t^g + \alpha_2\epsilon_t^y + \epsilon_t^m,$$

where $\hat{\pi}$ is a constant.[6]

To specify behavior in the goods market, we first assume that output growth is given by,

$$(2') \qquad \Delta y_t = \hat{y} + \alpha_3\epsilon_t^g + \epsilon_t^y,$$

where $\hat{y}$ is a constant.[7] This equation states that output growth is contemporaneously determined by changes in government spending and by a white noise error term, ϵ_t^y (labeled the real shock), which can be interpreted as a supply shock or any contemporaneous aggregate demand disturbance other than changes in government spending. Through this specification, monetary shocks are allowed to

[5]Statistical tests indicate the presence of a unit root in the inflation rate. The results of all such tests are available on request.

[6]With our methodology, ϵ_t^m includes all factors that contemporaneously influence inflation but are uncorrelated with government spending and output shocks. Wage and price controls could be included here. These often play an important role in stabilization programs, although this is not as true for Mexico as it is for other countries such as Brazil (see Bruno, DiTella, et. al.).

[7]Notice that we do not separately identify goods demand from supply. Blanchard and Quah (1989) make this separate identification based on the long-run restriction that demand shocks have no permanent effects on output growth. Under the Bernanke (1986) approach adopted in this paper, it is impossible to differentiate goods demand from supply, in particular when the government (i.e., fiscal and monetary) rules are generalized as in equations (3) and (4) below.

affect output only with a lag, as is consistent with conventional views of the monetary transmission mechanism.[8] We expect α_3 to be non-negative.

We next model the behavior of the government to complete the specification of the goods market. In order to relate the government spending process with the budget deficit, some preliminary discussion of the latter is needed. First, for econometric convenience, we define the "deficit" as the ratio of government spending to tax revenues, so that the log of the deficit is $d_t = \ln(G/T)_t$. Second, we assume that the change in government spending, denoted by Δg_t, is a stationary shock: $\Delta g_t = \epsilon_t^g$. Third, tax revenue is related to the level of output and the rate of inflation. The expected effect of output shocks on tax revenue (the budget deficit) is positive (negative) in the presence of automatic stabilizers such as a progressive income tax structure. The effect of inflation on tax revenue is designed to account for the possibility of the "Tanzi effect" - high inflation may lower tax revenue and worsen the fiscal deficit because it creates the incentive for private agents to delay paying taxes as long as possible.[9] Accordingly, we specify the deficit to be given by

$$\Delta d_t = d_o + \alpha_4 \Delta y_t + \alpha_5 \Delta \pi_t + \epsilon_t^g, \tag{3}$$

where d_o is a constant. We assume that $\alpha_4 < 0$. Notice that the Tanzi effect is present if $\alpha_5 > 0$. We can now rewrite (1′) and (2′), using (3), as follows:

$$\Delta \pi_t = \pi_o + [Z/(1+\alpha_5 Z)]\Delta d_t + [(\alpha_2 - \alpha_4 Z)/(1+\alpha_5 Z)]\Delta y_t + \hat{\epsilon}_t^m, \tag{1}$$

$$\Delta y_t = y_o + [\alpha_3/(1+\alpha_4\alpha_3)]\Delta d_t - [\alpha_5\alpha_3/(1+\alpha_4\alpha_3)]\Delta \pi_t + \hat{\epsilon}_t^y \tag{2}$$

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[8]We examined an alternative specification that allows ϵ_t^m to enter directly into the output equation, as in monetary business cycle models. This alternative modeling choice only alters one of the restrictions on the c coefficients [in particular, the first equation of (10) below], thus by itself generating a relatively minor difference. Such a specification comes at some cost, however, as it adds another α coefficient to the model. We are able to identify ten α's given the present set-up, so the alternative modeling strategy would necessitate either our placing an additional zero restriction somewhere else or imply that we could not solve for the eleven α's. Admittedly, our restrictions are not consistent with some models, but identification restrictions always come at some cost.

[9]Higher inflation could lower the deficit, on the other hand, if there is sufficient "bracket creep," for example.

where $\hat{\epsilon}_t^m = [1/(1+\alpha_5 Z)]\epsilon_t^m$, $\hat{\epsilon}_t^y = [1/(1+\alpha_4\alpha_3)]\epsilon_t^y$, and $Z = \alpha_1 - \alpha_3\alpha_2$.

We now turn to study the money market. With M being the log of the nominal money stock, let $m_t = (M_t - s_t)$, where s_t is the nominal exchange rate. In log form, the real stock of money is $M_t - p_t$. Using the log of the real exchange rate, $R_t = s_t + p_t^* - p_t$, where the asterisk indicates the foreign price level (which we assume has a constant growth rate),[10] equilibrium real balances are given by,

$$\Delta m_t = \Delta(M_t - s_t) = \Delta(M_t - p_t) - \Delta R_t$$

$$= [\hat{m} + \alpha_6\epsilon_t^g + \alpha_7\epsilon_t^y + \alpha_8\Delta i_t + \epsilon_t^d] - \Delta R_t, \qquad (4')$$

where $\hat{m}$ is a constant and i denotes the nominal interest rate. That is, we allow equilibrium real money balances to be contemporaneously correlated with nominal interest rates, as well as fiscal and output shocks, with the residual ϵ_t^d being labelled a domestic money balances shock. Under a general money supply feedback rule with respect to fiscal and output disturbances, the equilibrium money stock, M_t, may capture both demand and supply side responses, and thus economic theory does not definitely suggest signs for α_6, α_7, and α_8. Instead, we rely on the estimation results to determine the nature of the responses.

Noting that we can use the goods market to identify ϵ_t^g and ϵ_t^y in equation (4′), we must now model the nominal interest rate and real exchange rate. We first discuss interest rate determination. A particular problem with data in high inflation countries is that we have little confidence that the available interest rate series reflect market forces.[11] Accordingly, we eliminate the interest rate

[10]Allowing for a non-constant foreign inflation rate implies only that shocks to foreign inflation would be included in ϵ_t^R, which is specified below. A real depreciation occurs when $\Delta R_t > 0$.

[11]An indication of this comes from Blanco and Garber (1986), who use the U.S. interest rate less the forward discount on peso futures to represent the Mexican interest rate, because "Mexican capital markets were underdeveloped and the interest rates for bank liabilities were controlled (p.158)."

from the money market equilibrium condition by appealing to interest rate parity. Specifically, we assume that uncovered interest rate parity holds up to an error term and that expectations are rational:

(5a) $$i_t = i^* + \Delta s_t^e + u_t^i,$$

(5b) $$\Delta s_t^e = \Delta s_t + u_t^s.$$

Here, i is the nominal interest rate, the "e" superscript indicates the expected value next period, u_t^i is the deviation from uncovered interest parity, and u_t^s is a random prediction error.[12] Substituting (5b) into (5a), taking the first-difference, and using the definition of the real exchange rate,:

(6) $$\Delta i_t = \Delta^2 s_t + \epsilon_t^i = i_o + \Delta R_t + \Delta \pi_t + \epsilon_t^i,$$

where $\epsilon_t^i = \Delta u_t^i + \Delta u_t^s$ captures both variations in the "risk premium" and changes in prediction errors.[13] Substituting the second equality for the interest rate term in the money demand function then eliminates explicit consideration of the rate of interest from the analysis. In particular, equation (4′) may now be written as:

(4) $$\Delta M_t - \Delta s_t = m_o + W\Delta d_t + (\alpha_7 - \alpha_4 W)\Delta y_t - (\alpha_5 W - \alpha_8)\Delta \pi_t - (1-\alpha_8)\Delta R_t + \epsilon_t^A,$$

where $W = (\alpha_6 - \alpha_3\alpha_7)$ and $\epsilon_t^A = (\epsilon_t^d + \alpha_8 \epsilon_t^i)$. We expect that $\alpha_8 < 1$, so that the net effect of a real depreciation is to lower real balances. Note that ϵ_t^A, which is a combination of the domestic money demand shock, the risk premium and the expectational error in the foreign exchange market, is

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[12]The shock u_t^i could be interpreted as a time-varying risk premium, although there is no consensus explanation for deviations from uncovered interest parity. See Froot and Thaler (1990).

[13]The right hand side of (6) is derived as follows. From the definition of the real exchange rate, $\Delta R_t = \Delta s_t - \Delta p_t + \Delta p_t^* = i_o + \Delta s_t - \pi_t$, where $i_o = \Delta p^*$ is by assumption time-invariant. Rearranging and differencing again, we obtain $\Delta^2 s_t = \Delta^2 R_t + \Delta \pi_t = \Delta R_t - \Delta R_{t-1} + \Delta \pi_t$, which we substitute in after the first equality on the right hand side of equation (6). Because it is required to justify only the zero restrictions on the contemporaneous correlations between first-stage innovations in order to identify the VAR, the lagged term $(-\Delta R_{t-1})$ is omitted from explicit consideration in (6).

heavily influenced by external factors.[14] This is important for interpreting our empirical results, which attempt to assess the relative importance of the balance of payments view of inflation.

Finally, we close the model by postulating that changes in the real exchange rate are contemporaneously correlated with fiscal shocks, monetary shocks, and an own shock,

$$(7') \qquad \Delta R_t = \hat{R} + \alpha_9\epsilon_t^g + \alpha_{10}\epsilon_t^m + \epsilon_t^R,$$

where $\hat{R}$ is a constant. Equation (7′) implies that ϵ_t^R can be interpreted as any contemporaneous disturbance that affects R but is uncorrelated with changes in government spending or money growth. An example of such a disturbance is a nominal exchange rate collapse prompted by a balance of payments crisis. Under either fixed or flexible exchange rates, we expect an expansionary monetary policy will lead to a contemporaneous real depreciation, so that $\alpha_{10} > 0$ (this would be the result in a fixed-price Mundell-Fleming model, for instance). On the other hand, the expected sign of α_9 is unclear. Under high or perfect (low or zero) capital mobility in a Mundell-Fleming model with flexible exchange rates, for example, the sign is negative (positive).[15] In addition, Penati (1987) shows in a Sidrauski-type model that a fiscal expansion causes a real depreciation if the expansion falls primarily on traded goods, but either a real depreciation or appreciation if the expansion is mostly on non-traded goods. Using (1) and (4), we can rewrite (7′) as,

$$(7) \qquad \Delta R_t = R_o + (\alpha_9\text{-}\alpha_{10}Z)\Delta d_t - [\alpha_4(\alpha_9\text{-}\alpha_{10}Z)+\alpha_2\alpha_{10}]\Delta y_t + [\alpha_{10}\text{-}\alpha_5(\alpha_9\text{-}\alpha_{10}Z)]\Delta\pi_t + \epsilon_t^R$$

Estimation

Equations (1)-(4) and (7) form a fifth-order system in Δd_t, Δy_t, $\Delta\pi_t$, ΔR_t, and Δm_t. As noted in the previous section, we follow Bernanke (1986) in identifying the model by orthogonalizing the

[14]It is plausible that changes in Mexican domestic money demand are due to external factors, as are the risk premium and expectational errors in the foreign exchange market. For example, Ortiz (1983) and Rogers (1992) empirically document the significance of currency substitution in Mexico; the $(1\text{-}\alpha_8)$ term in equation (4) would reflect such a phenomenon.

[15]Notably, before August 1982, Mexico pursued a fixed exchange rate regime, while afterward there was a managed float.

residuals from the first-stage VAR using this system. This is done by placing zero restrictions on the <u>contemporaneous correlations between the innovations</u> from the first-stage equations. Writing all endogenous variables (Δd, Δy, $\Delta\pi$, ΔR, and Δm) in terms of their innovations (w^d, w^y, w^π, w^R, and w^A), the estimated system can thus be expressed as:

$$\begin{bmatrix} w_t^d \\ w_t^y \\ w_t^\pi \\ w_t^R \\ w_t^A \end{bmatrix} = \begin{bmatrix} d_o \\ y_o \\ \pi_o \\ R_o \\ m_o \end{bmatrix} + \begin{bmatrix} 0 & c_{12} & c_{13} & 0 & 0 \\ c_{21} & 0 & c_{23} & 0 & 0 \\ c_{31} & c_{32} & 0 & 0 & 0 \\ c_{41} & c_{42} & c_{43} & 0 & 0 \\ c_{51} & c_{52} & c_{53} & c_{54} & 0 \end{bmatrix} \begin{bmatrix} w_t^d \\ w_t^y \\ w_t^\pi \\ w_t^R \\ w_t^A \end{bmatrix} + \begin{bmatrix} \epsilon_t^g \\ \hat{\epsilon}_t^y \\ \hat{\epsilon}_t^m \\ \epsilon_t^R \\ \epsilon_t^A \end{bmatrix} \qquad (8)$$

where d_o, y_o, π_o, R_o and m_o are constants, and where:

$c_{12} = \alpha_4$; $c_{13} = \alpha_5$; $c_{21} = \alpha_3/(1+\alpha_4\alpha_3)$; $c_{23} = -\alpha_5 c_{21}$; $c_{31} = Z/(1+\alpha_5 Z)$;
$c_{32} = (\alpha_2-\alpha_4 Z)/(1+\alpha_5 Z)$; $c_{41} = (\alpha_9-\alpha_{10}Z)$; $c_{42} = -\alpha_4 c_{41}-\alpha_2\alpha_{10}$; $c_{43} = \alpha_{10}-\alpha_5 c_{41}$;
$c_{51} = W$; $c_{52} = \alpha_7-\alpha_4 W$; $c_{53} = \alpha_8-\alpha_5 W$; $c_{54} = \alpha_8-1$; and $Z = \alpha_1-\alpha_3\alpha_2$, $W = (\alpha_6-\alpha_3\alpha_7)$,
$\hat{\epsilon}_t^y = \epsilon_t^y/(1+\alpha_4\alpha_3)$, $\hat{\epsilon}_t^m = \epsilon_t^m/(1+\alpha_5 Z)$, and $\epsilon_t^A = (\epsilon_t^d+\alpha_8\epsilon_t^i)$.

Notice that we have normalized ϵ_t^y (ϵ_t^m) in such a way that the real (money growth) shock has a one-to-one effect on output (inflation) innovations. As discussed above, our model is just-identified, because there are exactly ten α_i coefficients ($\alpha_1,\ldots,\alpha_{10}$) to be estimated in the VAR system (8). Using the elements c_{ij} from (8), these coefficients can be written as:

$$\begin{aligned} &\alpha_1 = (c_{31}+c_{21}c_{32})/[(1-c_{31}c_{13})(1-c_{21}c_{12})]; \quad \alpha_2 = (c_{12}c_{31}+c_{32})/(1-c_{31}c_{13}); \quad \alpha_3 = c_{21}/(1-c_{12}c_{21}); \\ &\alpha_4 = c_{12}; \quad \alpha_5 = c_{13}; \quad \alpha_6 = (c_{51}+c_{21}c_{52})/(1-c_{12}c_{21}); \quad \alpha_7 = c_{52}+c_{12}c_{51}; \qquad (9) \\ &\alpha_8 = 1+c_{54}; \quad \alpha_9 = (c_{41}+c_{31}c_{43})/(1-c_{31}c_{13}); \quad \alpha_{10} = c_{43}+c_{31}c_{41} \end{aligned}$$

Notice from (9) that we need only ten of the thirteen elements c_{ij} to estimate the ten α_i coefficients. We do restrict c_{23}, c_{42} and c_{53} in the estimation because they can be written as combinations of the other elements:

$$
\begin{aligned}
c_{23} &= -c_{13}c_{21} \\
c_{42} &= [c_{43}(c_{12}c_{31}+c_{32})+c_{41}(c_{32}c_{13}+c_{12})]/(c_{31}c_{13}-1) \\
c_{53} &= 1+c_{54}-c_{13}c_{51}.
\end{aligned}
\tag{10}
$$

Note that, unlike the Bernanke structural VAR approach used here, the atheoretical methodology typically involves checking the robustness of results to different orderings of the variables. In our case, reordering the variables while maintaining the same zero restrictions between innovations has absolutley no effect on the results. On the other hand, changing the zero restrictions alters the economic meaning of the orthogonalized innovations because it changes the underlying model. In particular, we may not be able to identify the structural model from the reduced form.

IV. Results

We estimate (8) with restrictions (10) using monthly data from January 1977 to June 1990, thus beginning after the 1976 crisis. We then perform analysis of impulse responses and variance decompositions to study the dynamic effects of fiscal, real, monetary, exchange rate, and asset shocks (all of which are orthogonal) on the deficit, output, and inflation. All of our data comes from the central bank of Mexico's Indicadores Economicos. These are: (1) Government spending/tax ratio, ln(G/T), labelled D; (2) Output, y, labelled Y; (3) Inflation, π, labelled DP; and (4) Real exchange rate, R, labelled R; and (5) Real money balances, (M-s), labelled MS. The levels and first-differences of the variables used in the VAR are plotted in figures A (included in an appendix available on request).[16]

Structural Model Estimates

Table 1 displays the estimates of c_{ij} with t-statistics in parenthesis. The estimates are plausible, and five of the ten have t-ratios greater than 2.0.[17] We use these estimates and (9) to derive the α coefficients, which are also in Table 1. The estimated α's match the predictions of our illustrative model, suggesting a sound basis for the main results in the next section.

The coefficients α_1 (= -0.03) and α_2 (= 0.23), respectively, measure the contemporaneous effects of fiscal and real shocks on inflation. The former is negative but small. That α_2 is positive suggests either that e^y represents an aggregate supply shock affecting inflation with a lag or is an aggregate demand shock. The coefficient α_3 (= 0.06) is a reasonable estimate of the contemporaneous effect of government spending on output. The estimate of α_4 (= -4.36) indicates the output shock contemporaneously lowers the budget deficit (through higher tax revenue). Note that α_5 = 12.2 implies a positive relationship between inflation and the budget deficit, which suggests that the Tanzi (1977) effect is present, and the t-statistic of 4.01 (see C_{13}) indicates the effect is highly

[16]In estimating the model, we have paid special attention to possible structural shifts that may have occurred due to the factors discussed in section II. Such breaks can be captured through two channels, i.e., by changes in (a) the variances of the disturbances, and (b) the responses of the endogenous variables to shocks. We address (a) by testing for the constancy of the reduced-form variances. First, we obtain the ratios of the estimated variances before and after the midpoint of the sample. We then test for the homoscedasticity of each of the five error terms in the unrestricted VAR. The test statistics for the first through fifth elements of the error vector are 1.39, 1.27, 1.67, 1.94, and 2.15. The critical value of the $F_{.05}(35,35)$ [$F_{.01}(35,35)$] statistic is about 1.76 [2.25]. Thus, the error terms generally display constant variances. We show that channel (b) is important only to a small degree using the historical decompositions of section V.

[17]The standard errors obtained from this estimation procedure are usually large. For example, Bernanke (1986) finds as few as two of fifteen estimated coefficients have t-ratios greater than 2.0. Fackler (1990), who finds only five of twenty-eight coefficients with t-statistics in excess of 2.0, also notes this phenomenon and speculates on the reasons for it. In comparison, our estimates are relatively precise.

significant. Next is the equation for equilibrium real money balances. The estimate $\alpha_6 = 0.02$ indicates that the feedback from government spending to money growth is positive; the estimate of α_7 (= -0.22), which measures the feedback from output to money growth, reflects a countercyclical monetary policy; and α_8 (= 0.01) implies an upward-sloping money supply function. From these estimates, it is appropriate to interpret the residual ϵ^d, as a money demand shock. The real exchange rate equation includes α_9 (= -0.12) and α_{10} (= 2.69), which imply that fiscal expansion or monetary contraction leads to a contemporaneous real appreciation, as expected.

Impulse Response Functions and Variance Decompositions

In this section, the impulse response functions (IRFs) and variance decompositions (VDCs) are analyzed. IRFs show the predictable response of each variable to a one standard error shock to one of the system's variables. The VDCs show the fraction of forecast error variance for each variable that results from its own innovations and from shocks to the other system variables.

Figure 1 contains the impulse response functions, displaying the response of changes in the deficit, output and inflation to each shock (fiscal, real, money growth, exchange rate, and asset). We present the point estimates and a 90 percent confidence band (based on Monte Carlo integration with 1000 draws). Figures 1a show that there is a positive and significant impact effect on the deficit from fiscal shocks, money growth shocks, and the asset shock. Figures 1b indicate that the impact effects of real shocks and asset shocks on output growth are significantly positive. Figures 1c indicate that inflation responds positively and significantly to all shocks initially (at the two-month horizon in the case of fiscal shocks). Note that the response of inflation to the money growth shock is the strongest, while the effects of fiscal and asset shocks are approximately equal. We interpret these results below.

In the variance decompositions of table 2, we report point estimates and standard deviations at the 6-month and 48-month horizons. We focus discussion on the deficit, output and inflation, but have included the VDCs of all the variables. According to the first row of table 2, approximately 30 percent of the forecast error variance of changes in the deficit are explained by the fiscal shock, while the monetary shock (which has a one-to-one contemporaneous effect on inflation) accounts for nearly one-half. The latter suggests that higher inflation is an important reason for higher budget deficits, i.e., that the Tanzi effect is present. Output growth is affected primarily by the own shock (which is a supply shock or an aggregate demand disturbance other than changes in government spending), and somewhat so by the asset shock. The fiscal shock accounts for 20 percent of the variance of output growth, but it also has a large standard error. The variance of inflation is explained approximately equally by fiscal and monetary shocks, each of which accounts for about 30 percent. In addition, real shocks account for about 15 percent of the variance of inflation, while the combined contribution of exchange rate and asset shocks (to be interpreted as broadly-defined "external" shocks based on the model of section III) is approximately 25 percent.

Interpretations and Comparisons

Two related papers are Dornbusch, Sturzenbegger, and Wolf (1990) and Ize and Salas (1985). Dornbusch, Sturzenbegger, and Wolf (1990) adopt Blanchard and Quah's (1989) structural VAR approach to examine sources of inflation in several high inflation countries, including Mexico. Using the ratio of changes in the monetary base to the price level as a proxy for the deficit, they find that exchange rate and fiscal shocks are equally important; the two account for more than 80 percent of the variance of inflation over the period 1975-1987. Notice that the fiscal shock in Dornbusch, Sturzenbegger, and Wolf can be regarded as a combination of our fiscal and money growth shocks, which account for 60 percent of the variance of inflation in our results. In addition, notice that at longer horizons ϵ_t^R and ϵ_t^A combined account for as much of the variance of inflation as the fiscal shock or the money growth shock individually. Assuming that (1) the relevant comparison is between domestic and external disturbances broadly defined, and (2) our asset shock (a combination of the domestic money demand shock, the risk premium, and the expectational error in the foreign exchange market) is driven primarily by external factors, then "external" shocks are as influential as any others in our model. Under these conditions, therefore, our results concerning the sources of fluctuations in inflation are qualitatively consistent with Dornbusch, Sturzenbegger, and Wolf (1990).[18]

Ize and Salas (1985) use simultaneous equations estimation to conclude that Mexican inflation from 1961 to 1981 is mostly supply-push. Although we do find that real shocks play some role in the inflation process (over our sample period of 1977-1990), more important effects come from fiscal, monetary, and "external" shocks. Thus our results differ even if ϵ_t^Y is entirely a supply shock.

V. Model Diagnostics

We analyze the historical decompositions (HDCs) in order to assess the sensitivity of the innovation accounting results over sub-periods.[19] HDC analysis begins by estimating a "base projection" (BP) of any particular series. The base projection is computed by estimating the model up to a break date and using the estimated model to forecast future values of the series. The HDC credits each shock for explaining the difference between the BP and the actual series. A shock is "important" to the extent that it lessens that difference. By analyzing several sub-periods, we assess potential structural changes by looking for changes in the relative importance of the shocks. We analyze periods following the first attempts at stabilization in late 1981.

We compute the HDCs for the deficit, output and inflation (in first-differences). First, we estimate the model up to 9/81 and calculate BPs of the deficit, output, and inflation through the end of the sample (6/90). The HDCs over this period are displayed in the first column in Table 3A. We also divide the period from 9/81 to 6/90 into four sub-periods - 9/81-6/84, 7/84-8/85, 9/85-12/87,

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[18]Our results concerning the relative influence of "domestic" versus "external" shocks on inflation are also consistent with those of Montiel (1989), who studies Argentina, Brazil, and Israel using quarterly data.

[19]We discuss derivation of the HDCs in Appendix B. We could calculate VDCs over each sub-period instead of computing HDCs, but not given the dimensions of our VAR and the time horizon.

and 1/88-6/90 - and compute the HDCs over them. These results are in the next four columns of Table 3A, respectively. We then repeat the analysis estimating the model up to 6/84 and examining the sub-periods 6/84-8/85, 9/85-12/87, and 1/88-6/90. These results are in Table 3B. The importance of the chosen split dates is noted in section II.

In Tables 3 we report the sum over each of the sub-periods of (1) the root mean square error (RMSE) for the base projection [e.g., (BP_t less the actual value of ouput), squared], (2) the RMSE for the BP plus the contribution of each shock [e.g., {$[BP+\text{the fiscal shock}]_t$ less the actual value of output}, squared], and (3) the ratio of (2) to (1) in parenthesis.[20]

To assess possible structural changes, compare across columns the value in parenthesis for any row. The contribution of real shocks on the HDC of inflation is given in the row labelled BP+y under $\Delta\pi$ in Table 3A. The number in parenthesis in the first column (= 0.90) says that real shocks reduce the root mean square error of the BP of inflation by 10% over the period 9/81-6/90. In the next column, the number in parenthesis (= 0.93) tells us that during the sub-period 9/81-6/84 there is a 7% reduction in the RMSE of inflation due to real shocks. Over the remaining three sub-periods, the corresponding numbers are 0%, 13%, and 11%. One can also analyze the analogous row and columns under Table 3B, in which BPs are calculated using data through 6/84 only. The reduction in the RMSE of inflation due to real shocks is 3% over the period 6/84-6/90, and 2%, -1%, and 10% over the three sub-periods within those years.

In general, the HDCs are qualitatively consistent with the full-sample VDCs. However, some quantitative differences across sub-periods are worth noting. First, the Tanzi effect (of inflation on the deficit) is more apparent before 8/85, while the output effect on the deficit is more important after 9/85. Second, concerning the HDC of output, the importance of fiscal shocks increased after 9/85,

[20]A low value in parenthesis indicates that shock is important in explaining deviations from the BP; a value greater than unity implies those shocks move the projection further from the actual series.

while the real balance effects emphasized in monetary business cycle models are not strong until 1/88. Finally, the effects of fiscal shocks on inflation are especially influential in the periods of 9/81-6/84 and 1/88-6/90, which correspond to the periods of crisis and stabilization, respectively.

VI. Conclusion

We estimate a model explicitly identifying shocks which may be sources of movements in Mexican output and inflation. Our results suggest that output is influenced primarily by real shocks. Inflation is explained in part by all five shocks, with fiscal and money growth shocks being the most influential. Thus we find strong support for the "fiscal view" of inflation. Exchange rate shocks are also significant, and, because our asset shock is likely to driven by external factors, we find support for the balance of payments view in that broadly-defined "external" shocks are influential. We also find that higher inflation and higher budget deficits cause each other to spiral upward via the Tanzi effect. The policymaking implications emerging from the Mexican case suggest that inflation stabilization does require a reduction in money-financing of budget deficits. The stabilization in Mexico which began in late 1988, and failed attempts at stabilization in Brazil which did not involve fiscal correction, are testimony to this. However, our results also indicate that even successful implementation of such traditional policies may not be enough if external forces are unfavorable.

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Table 1; Model Estimates

Coefficient:	C_{12}	C_{13}	C_{21}	C_{23}a	C_{31}	C_{32}
	-4.36 (-0.42)	12.2 (14.0)	0.09 (0.26)	-1.10	-0.11 (-2.76)	0.06 (0.07)

C_{41}	C_{42}a	C_{43}	C_{51}	C_{52}	C_{53}a	C_{54}
0.002 (0.02)	-0.61	2.66 (4.60)	0.04 (2.17)	-0.07 (-0.55)	-0.43	-0.99 (-32.0)

Coefficient:	α_1	α_2	α_3	α_4	α_5
	-0.03	0.23	0.06	-4.36	12.2
	α_6	α_7	α_8	α_9	α_{10}
	0.02	-0.22	0.01	-0.12	2.69

Note: (a) This coefficient is restricted in the estimation, and is computed using (10).

Table 2; Variance Decompositions

shock/ response of:	fiscal	real	monetary	exchange rate	asset
Δd	34.6/29.7* (16.9)(12.6)	12.4/13.1 (18.5)(12.3)	50.9/44.6* (17.4)(12.9)	1.30/3.34 (2.12)(4.05)	0.75/9.34* (1.16)(4.16)
Δy	20.7/20.9 (20.9)(15.9)	70.2/59.9* (21.1)(16.5)	2.23/5.42 (2.27)(3.59)	2.53/2.63 (2.71)(3.24)	4.30/11.2* (2.54)(6.62)
$\Delta \pi$	33.6/27.2* (14.2)(8.30)	14.3/16.0* (7.08)(5.01)	35.9/28.8* (14.2)(9.58)	3.98/6.32* (3.19)(3.57)	12.1/21.7* (3.34)(4.96)
ΔR	7.99/8.81* (4.48)(4.77)	4.16/5.58 (2.82)(3.73)	6.59/7.98 (5.23)(4.90)	80.6/74.3* (5.53)(7.49)	0.69/3.35 (1.19)(2.90)
$\Delta(M\text{-}s)$	9.93/10.9* (5.10)(4.77)	5.58/7.91* (3.23)(3.98)	5.27/7.45* (4.69)(4.47)	70.9/62.3* (5.38)(6.78)	8.34/11.5* (1.85)(3.41)

Note: (*) Significant at least at the 90% level of confidence. Entries give the percentage of the variance attributable to each shock at the 6-month and 48-month horizons. Standard errors in parenthesis are computed using 1000 random draws.

Table 3; Historical Decompositions - Changes in Deficit, Output and Inflation

A. Base projections computed using information up to 9/81 only:

RMSE	Dd(9/81-6/90)	Dd(9/81-6/84)	Dd(7/84-8/85)	Dd(9/85-12/87)	Dd(1/88-6/90)
BP	3.13	1.57	0.20	0.77	0.59
BP+d	1.02 (0.33)	0.30 (0.19)	0.08 (0.40)	0.22 (0.28)	0.43 (0.73)
BP+y	3.07 (0.98)	1.58 (1.01)	0.21 (1.05)	0.73 (0.95)	0.55 (0.94)
BP+π	3.23 (1.03)	1.31 (0.83)	0.18 (0.90)	0.77 (1.00)	0.97 (1.65)
BP+R	5.70 (1.83)	1.74 (1.11)	0.92 (4.52)	1.86 (2.43)	1.19 (2.02)
BP+m	9.21 (2.95)	4.00 (2.55)	1.11 (5.45)	2.79 (3.64)	1.32 (2.25)

RMSE	Dy(9/81-6/90)	Dy(9/81-6/84)	Dy(7/84-8/85)	Dy(9/85-12/87)	Dy(1/88-6/90)
BP	10.1	3.19	0.77	2.61	3.55
BP+d	9.86 (0.97)	3.25 (1.02)	1.00 (1.29)	2.15 (0.83)	3.47 (0.98)
BP+y	2.92 (0.29)	0.55 (0.17)	0.40 (0.52)	1.17 (0.45)	0.79 (0.22)
BP+π	9.64 (0.95)	3.13 (0.98)	0.87 (1.13)	3.02 (1.16)	2.62 (0.74)
BP+R	20.2 (2.00)	6.53 (2.05)	2.25 (2.91)	6.01 (2.31)	5.44 (1.53)
BP+m	22.9 (2.27)	8.06 (2.53)	2.80 (3.63)	6.37 (2.44)	5.70 (1.61)

RMSE	Dπ(9/81-6/90)	Dπ(9/81-6/84)	Dπ(7/84-8/85)	Dπ(9/85-12/87)	Dπ(1/88-6/90)
BP	2.23	0.73	0.14	0.84	0.53
BP+d	2.16 (0.96)	0.62 (0.85)	0.19 (1.32)	0.84 (1.00)	0.51 (0.95)
BP+y	2.02 (0.90)	0.67 (0.93)	0.14 (1.00)	0.73 (0.87)	0.47 (0.89)
BP+π	1.13 (0.50)	0.36 (0.49)	0.01 (0.68)	0.30 (0.36)	1.37 (0.71)
BP+R	7.96 (3.55)	3.97 (5.45)	0.69 (4.89)	1.81 (2.16)	1.49 (2.79)
BP+m	7.90 (3.53)	2.75 (3.78)	1.18 (8.33)	2.36 (2.83)	1.61 (3.02)

B. Base projections computed using information up to 6/84 only:

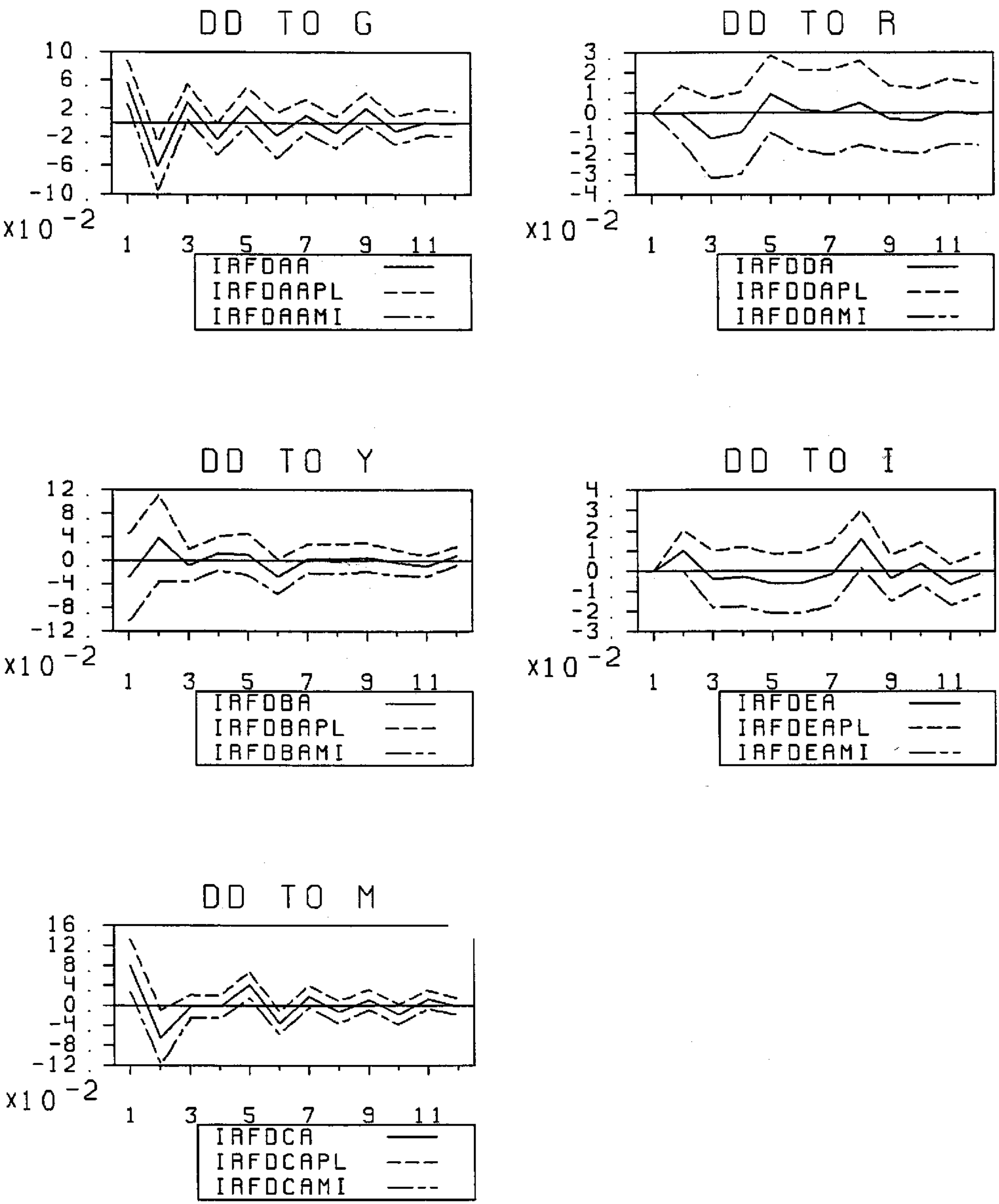
RMSE	Dd(6/84-6/90)	Dd(6/84-8/85)	Dd(9/85-12/87)	Dd(1/88-6/90)
BP	1.46	0.20	0.74	0.51
BP+d	0.58 (0.40)	0.02 (0.10)	0.18 (0.24)	0.38 (0.74)
BP+y	1.42 (0.98)	0.21 (1.01)	0.64 (0.86)	0.58 (1.14)
BP+π	1.85 (1.27)	0.21 (1.01)	0.80 (1.08)	0.85 (1.67)
BP+R	3.47 (2.39)	0.23 (1.14)	1.82 (2.44)	1.42 (2.80)
BP+m	2.23 (1.53)	0.20 (0.97)	1.11 (1.49)	0.93 (1.83)

RMSE	Dy(6/84-6/90)	Dy(6/84-8/85)	Dy(9/85-12/87)	Dy(1/88-6/90)
BP	6.45	0.56	2.38	3.52
BP+d	5.94 (0.92)	0.58 (1.04)	2.02 (0.85)	3.34 (0.95)
BP+y	2.11 (0.33)	0.17 (0.30)	1.12 (0.47)	0.82 (0.23)
BP+π	5.60 (0.87)	0.65 (1.17)	2.30 (0.97)	2.65 (0.75)
BP+R	13.8 (2.15)	0.89 (1.59)	5.25 (2.21)	7.71 (2.19)
BP+m	1.06 (1.64)	0.56 (1.01)	4.60 (1.94)	5.42 (1.54)

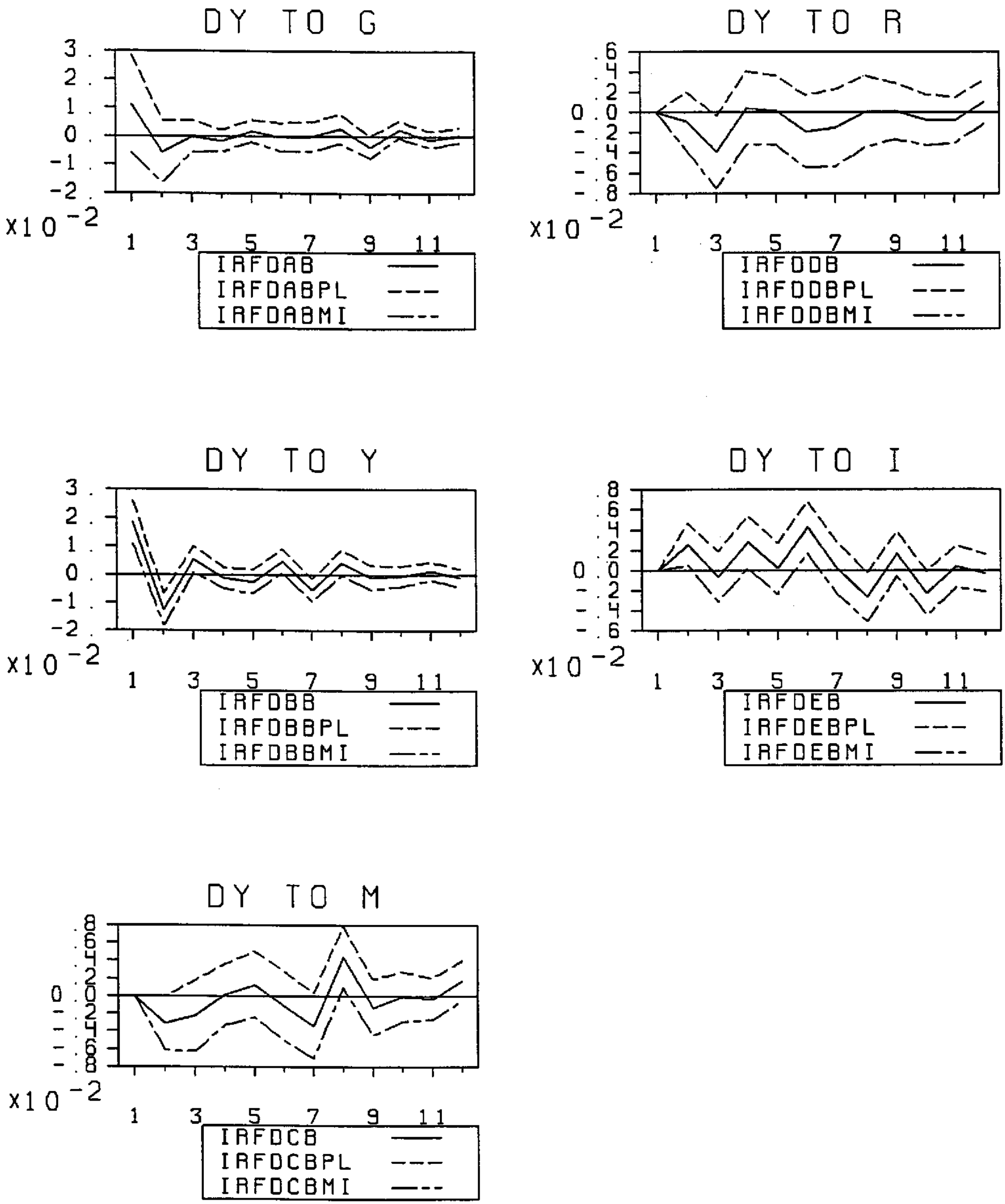
RMSE	Dπ(6/84-6/90)	Dπ(6/84-8/85)	Dπ(9/85-12/87)	Dπ(1/88-6/90)
BP	13.4	1.17	7.08	5.12
BP+d	13.2 (0.99)	1.37 (1.17)	6.98 (0.99)	4.85 (0.95)
BP+y	12.9 (0.97)	1.15 (0.98)	7.18 (1.01)	4.59 (0.90)
BP+π	5.76 (0.43)	0.37 (0.32)	2.27 (0.32)	3.12 (0.61)
BP+R	40.1 (3.05)	3.65 (3.11)	19.4 (2.74)	17.7 (3.46)
BP+m	38.5 (2.88)	2.46 (2.10)	17.8 (2.51)	18.2 (3.56)

Note: BP denotes the root mean square error of the base projection of output or inflation; BP+i is the RMSE of the base projection plus the contribution of shock i; in parenthesis is the ratio (BP+i)/BP - a low value indicates that shock i is important in explaining movements in output or inflation.

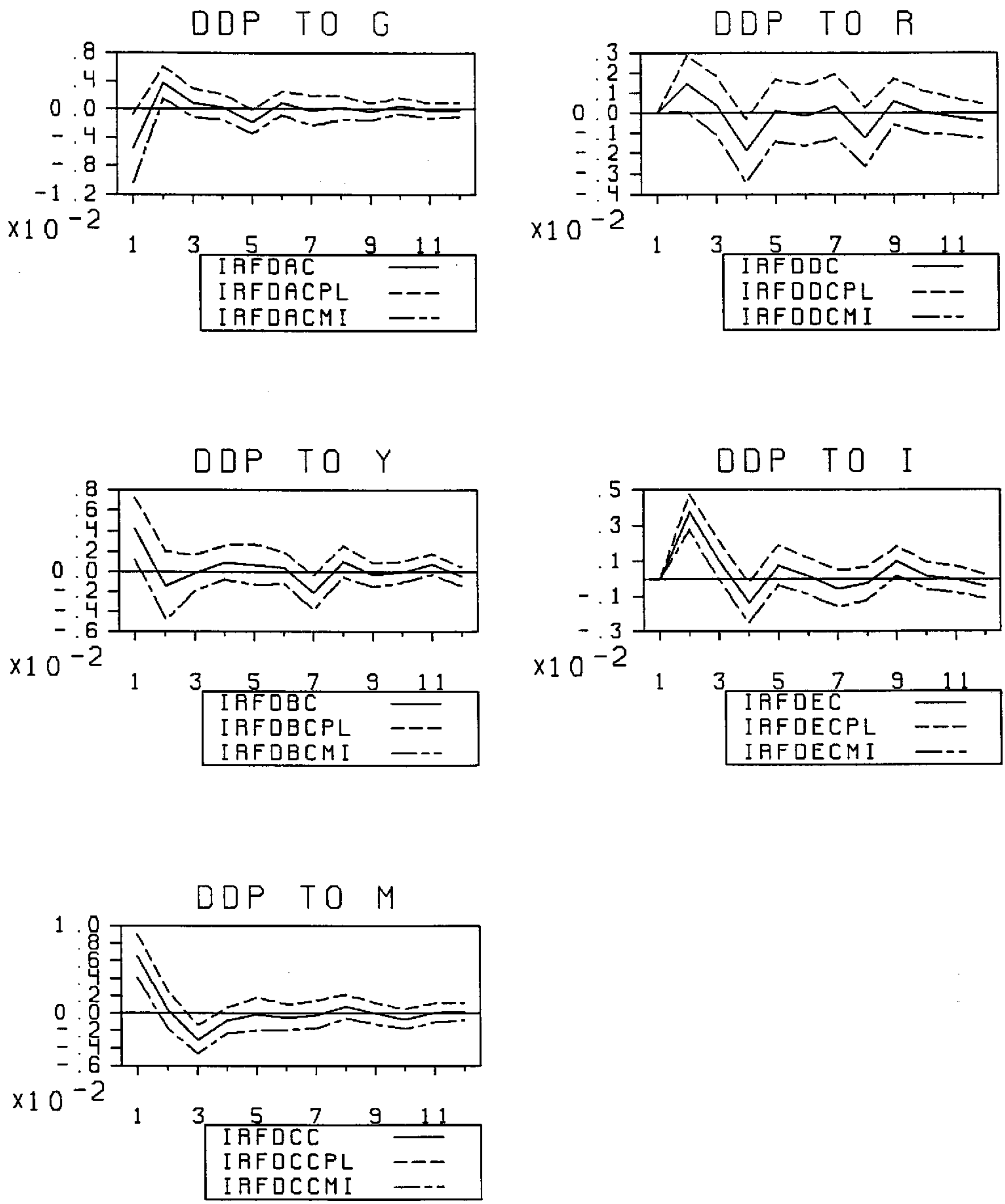
Figures 1a; Impulse Response Functions
Response of Deficit to Fiscal (G), Real (Y), Money Growth (M), Exchange Rate (R), and Asset Market (I) Shocks; Point Estimates and Confidence Band



Figures 1b; Impulse Response Functions
Response of Output to Fiscal (G), Real (Y), Money Growth (M), Exchange Rate (R), and Asset Market (I) Shocks; Point Estimates and Confidence Band



Figures 1c; Impulse Response Functions
Response of Inflation to Fiscal (G), Real (Y), Money Growth (M), Exchange Rate (R), and Asset Market (I) Shocks; Point Estimates and Confidence Band



APPENDIX A

The following data is monthly, from January 1977 to June 1990, taken from Economic Indicators, Central Bank of Mexico:

y = industrial production; P = consumer prices; G = nominal federal government expenditure; T = nominal federal government tax revenue; M = nominal M1; and s = nominal exchange rate, pesos per U.S. dollar.

APPENDIX B

Here we discuss the derivation of the VDCs and HDCs, and the calculation of standard errors. From (9), and denoting the expected value $E[\underline{\varepsilon}_t\underline{\varepsilon}_t'] = S$, note that we orthogonalize the covariance matrix of residuals from the unrestricted VAR by specifying a matrix C for which $E[\underline{v}_t\underline{v}_t'] = (I-C)S(I-C)' = M$, a diagonal matrix, where $\underline{v}_t$ is the vector of residuals from the first-stage VAR. The decomposition matrix is $F = (I-C)^{-1}M^{1/2}$. Thus $FF' = (I-C)^{-1}M[(I-C)^{-1}]' = (I-C)^{-1}[(I-C)S(I-C)'][(I-C)^{-1}]' = S$. In this way the matrix F is derived from the theoretical model (9).

Furthermore, since the k-period ahead forecast of $\underline{x}_t$ can be written,

$$\underline{x}_{t+k}=\underline{c}^{(k)}+\underline{\varepsilon}_{t+k}+H_1\underline{\varepsilon}_{t+k-1}+\ldots+H_{k-1}\underline{\varepsilon}_{t+1}+(I-C_1)^{(k)}\underline{y}_t+(I-C_2)^{(k)}\underline{y}_{t-1}+\ldots+(I-C_p)^{(k)}\underline{y}_{t-p+1},$$

its variance,

$$\begin{aligned}\mathrm{Var}(\underline{x}_{t+k}) &= S + H_1SH_1' + \ldots + H_{k-1}SH_{k-1}'\\ &= FF' + H_1FF'H_1' + \ldots + H_{k-1}FF'H_{k-1}'.\end{aligned}$$

Finally, since FF' is written trivially as,

$$FF' = F\left[\begin{vmatrix}1 & 0 & \ldots & 0\\ 0 & 0 & \ldots & 0\\ & \ldots\ldots & & \\ & \ldots\ldots & & \\ 0 & 0 & \ldots & 0\end{vmatrix} + \begin{vmatrix}0 & 0 & \ldots & 0\\ 0 & 1 & \ldots & 0\\ & \ldots\ldots & & \\ & \ldots\ldots & & \\ 0 & 0 & \ldots & 0\end{vmatrix} \ldots \begin{vmatrix}0 & 0 & \ldots & 0\\ 0 & 0 & \ldots & 0\\ & \ldots\ldots & & \\ & \ldots\ldots & & \\ 0 & 0 & \ldots & 1\end{vmatrix}\right]F'$$

we can decompose how much of the forecast error variance is due to each shock.

Notice that, were it impossible to find a decomposition of S, we would be unable to attribute the forecast error variances to the proper innovation. This is because unless S were by chance diagonal, the l-th element of $\underline{\epsilon}_t$ probably changes when the j-th element changes. The criticism from Bernanke (1986) and Cooley and LeRoy (1985) is that using the Choleski factorization provides no theoretical interpretation of the VDCs.

To derive the HDCs, write the moving average representation of the VAR,

$$\text{(B1)} \quad \underline{x}_t = \sum_{i=0}^{\infty} B_i \underline{v}_{t-i},$$

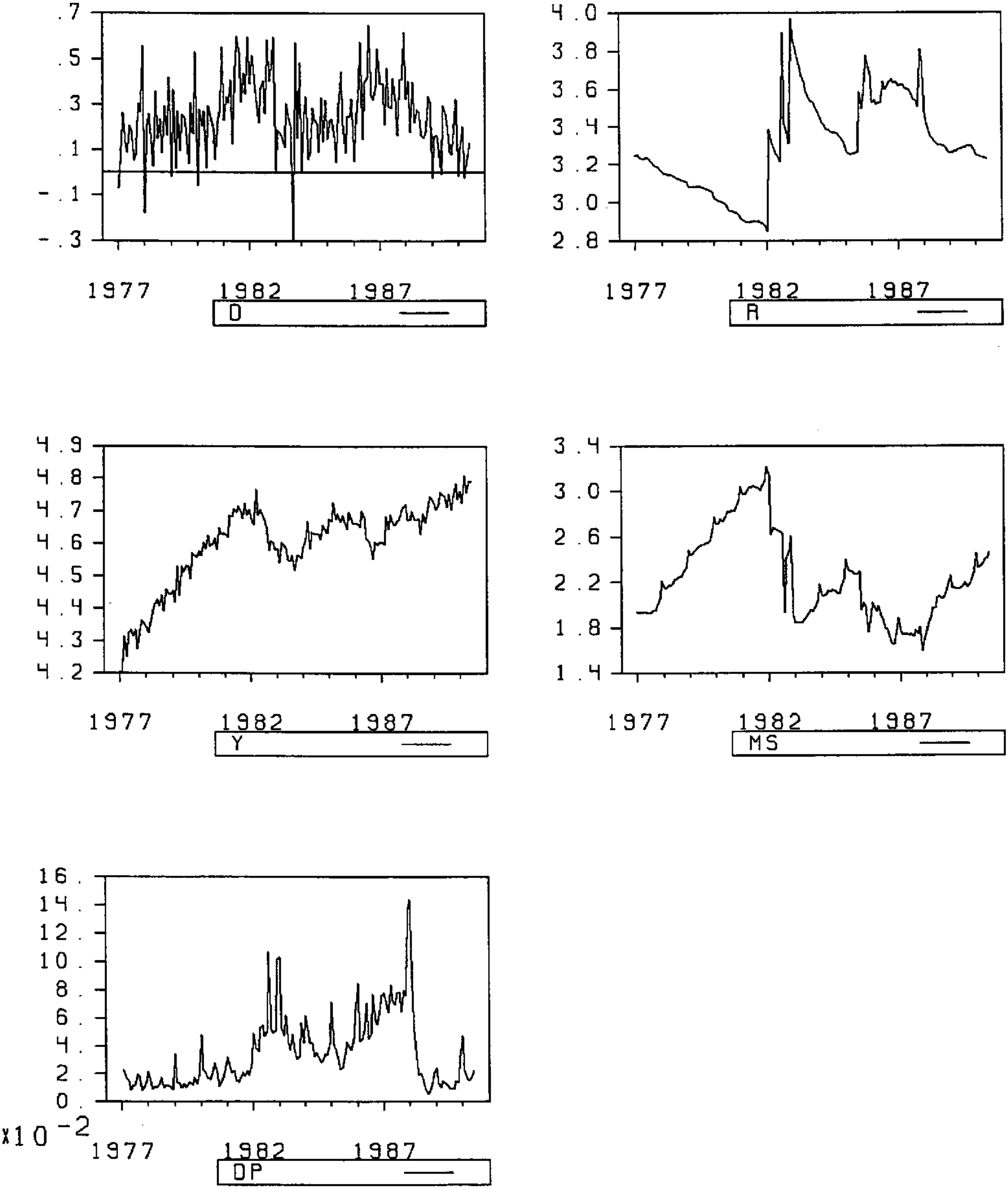
where $\underline{x}_t$ is a column vector of the system's variables, $\underline{v}_{t-i}$ a column vector of innovations in the elements of $\underline{x}$ in period t-i, and B_i is a matrix of impulse response weights. Consider a base period which runs from observation 1 (1/77) to T (e.g., 9/81). The value of $\underline{x}$ in periods subsequent to T can be written,

$$\text{(B2)} \quad \underline{x}_{t+j} = \sum_{i=j}^{\infty} B_i \underline{v}_{T+j-i} + \sum_{i=0}^{j-1} B_i \underline{v}_{T+j-i},$$

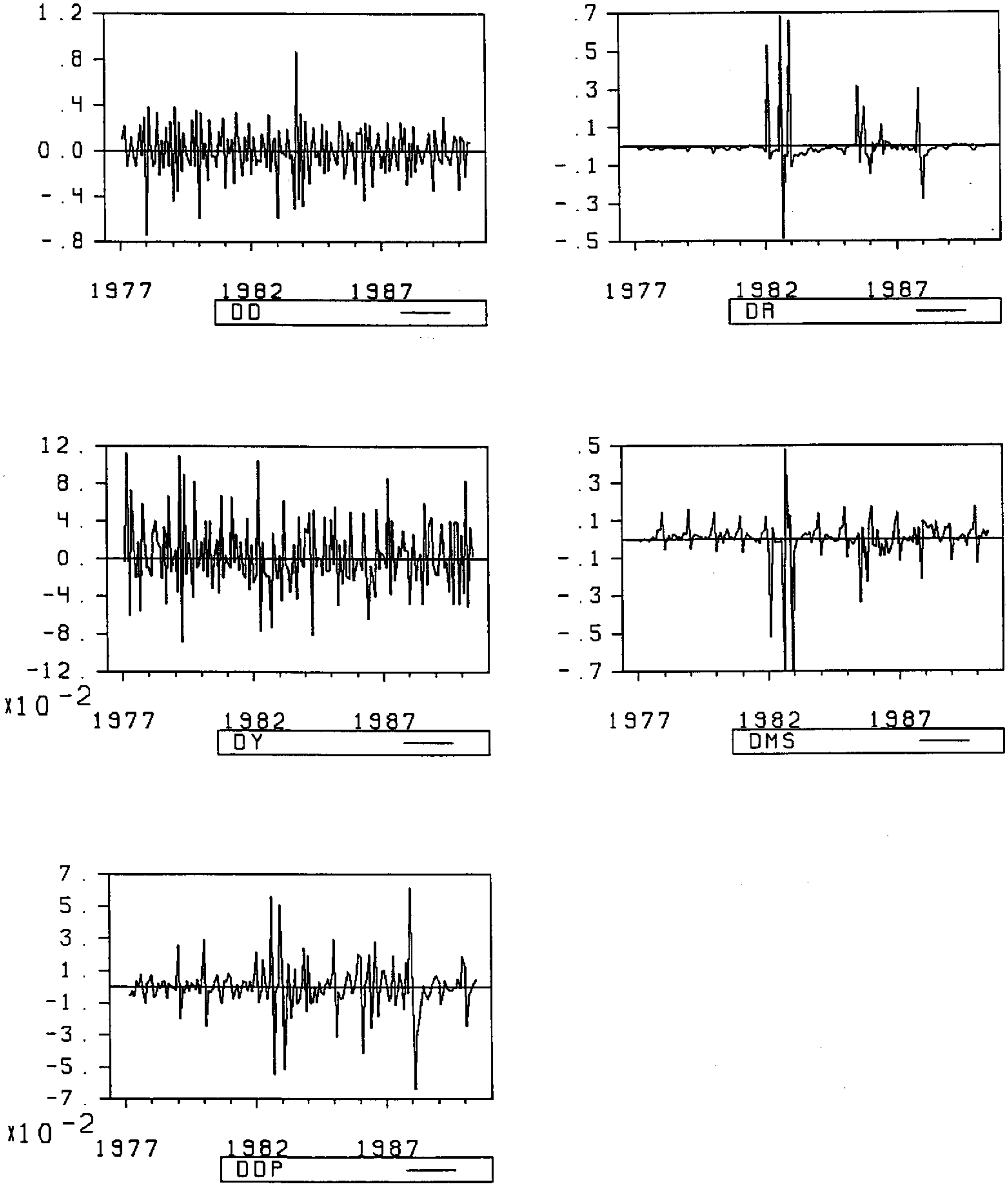
where the first term on the right-hand side of (B2) is the base projection (forecast) of $\underline{x}_{T+j}$ based only on information available at T, and the second term is the part of $\underline{x}$ accounted for by innovations since T. The elements of the second term are used to determine the "importance" of a particular variable(s) - the extent to which innovations in that variable close the gap between $\underline{x}_{T+j}$ and the base projection.

The standard deviations for the IRFs and VDCs are calculated by randomly taking draws from the elements of the covariance matrix of residuals from the unrestricted VAR. On each draw, another matrix of parameter estimates C_{ij} is calculated, from which a new decomposition matrix F is derived, and different observations of the forecast error variances are generated, as described above. The bands are drawn for a 90 percent confidence level.

Figures A; Plots of the Series - Levels
Budget Deficit (D), Output (Y), Inflation (DP)
Real Exchange Rate (R), and Real Money Balances (MS)



Figures A, cont'd; Plots of the Series - First Differences
Budget Deficit (DD), Output (DY), Inflation (DDP)
Real Exchange Rate (DR), and Real Money Balances (DMS)



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