INTERNATIONAL BUSINESS CYCLES

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I. Introduction

Macroeconomists have increasingly turned their attention to the study of business cycles in the last decade. For the most part, however, research has focused on the domestic economy. The focus of attention has been to identify the forces that induce fluctuations in economic variables in order to assess the importance of real versus nominal shocks in their propagation (e.g., Shapiro and Watson 1988). Less attention has focused on the international aspects of the business cycle.

This is not surprising given the early stage of this research and the complexities that arise in open economy models. Yet an international approach offers an interesting perspective for viewing the subject of business cycles.

In this paper we employ a two-country model of the international economy to explore the sources of economic fluctuations. Our purpose is to assess the importance of policy shocks (fiscal and/or monetary) and real shocks in propagating international business cycles. In particular we wish to assess the extent to which a common "international business cycle" is responsible for observed co-movements, or whether policy shocks play the major role.

A second goal of this paper is to study the transmission of shocks across economies and the role of exchange rate regimes in this process. Economists have theorized about the insulation properties of fixed and flexible exchange rates. Since the elaboration of the Mundell-Fleming model students have learned how monetary shocks are transmitted across countries under fixed exchange rates and about the insulation properties of flexible exchange rates. Yet there has been surprisingly little empirical analysis of this question.[1] There is a good reason why this is the case. Suppose you have identified the business cycles of several major industrial economies (by some time series

techniques) and that you calculate the cross correlations of these cycles for the period of fixed and floating rates. The results you obtain tell you little about relative transmission properties because common supply shocks could account for whatever results you obtain. Without a way to identify the role of supply shocks and the common international business cycle, comovements across countries cannot be taken as evidence of transmission.

We face this problem squarely by developing a model that allows us to identify domestic supply shocks and a common international supply shock. This enables us to infer the extent to which monetary and fiscal shocks are transmitted across international borders. We are able to assess the transmission properties of fixed and flexible exchange rates by examining the long-run effects of fiscal and monetary shocks in the two regimes. Light is shed on the importance of the various shocks by examining the variance decomposition under the two regimes.

Our modeling strategy is to develop a two-country model, the U.S. and the rest of the world. The model is utilized to characterize the long-run behavior of the economic aggregates in each "country." The structural model we develop is a long-run model--we do not restrict the short-run interactions between the variables. Rather we let the data decide this issue. By utilizing long-run restrictions only we are able to rely on less controversial assumptions then would be needed if we were to fully specify a short run structural model. The model is then estimated for the period 1960-86, by treating the U.K., West Germany, France, Canada, and Japan as the rest of the world.

The study of international correlation of business cycles has been conducted by a distinguished set of economists. Wesley Mitchell (1927) treated this question within the framework developed to summarize business

cycle phenomena. He found a positive correlation of business cycles across countries which was growing over time. This was measured by calculating the percentage of months when business cycles were in the same phase across countries. He attributed this to the growth in international financial linkages. Morgenstern (1959) compared the correlation of the business cycles in the U.S., U.K., France, and Germany under the gold standard (1879-1914) and the intervening period. He found that the business cycles were in phase more often in the gold standard period then in the later periods. Dornbusch and Fisher (1986), following Morgenstern, studied the period 1953-80. They studied the same countries, with essentially the same approach, and found less correlation than Morgenstern found.

An important recent contribution to this literature is Baxter and Stockman (1988). They employ modern time series techniques to identify business cycles in 44 countries.[2] The purpose is to see if the transmission process depends on the exchange rate regime. They find that business cycles have become more country specific in the flexible exchange rate period while the real exchange rate has become more volatile. They note, however, that with statistical methods alone "it is difficult to discriminate between the effects of changes in the exchange rate system and of other real disturbances" (Baxter and Stockman 1988:4-5). It is for this reason that we develop a macroeconomic model that allows for various types of shocks, so that we can distinguish between cross correlation due to the exchange rate regime and that due to a change in the pattern of study.

Our procedure in the rest of the paper is as follows. In section II we develop the long-run theoretical model and discuss the restrictions that we impose to allow us to identify the model and derive a system of linear equations that describe the paths of the endogenous variables. In section III

we discuss the econometric methodology used to estimate the model and present the results. We also discuss the effects of the exchange rate regime on the interaction between countries. Section IV discusses extensions.

II. Theoretical Framework

In this section we develop a simple two-country theoretical model of the world economy which is used to characterize the long-run behavior of economic aggregates in each country. Following some of the recent literature in macroeconomics (King, Plosser, Stock and Watson [1987], for example), we allow for the possibility that this long-run behavior is not deterministic but stochastic and represented by random walks.

Given the motivation for the paper discussed earlier, our theoretical model helps to serve two main purposes. First, it explicitly specifies the different shocks that could be potential sources of stochastic trends in the economic time series of different countries. In our most general theoretical model we allow for five different types of permanent disturbances: (i) a world technology shock which real business cycle theorists would argue is important; (ii) country-specific supply shocks, modelled here as labor productivity disturbances; (iii) country-specific fiscal policy shocks; (iv) country-specific monetary policy shocks; and (v) good-specific or relative demand disturbances, modelled here as preference shocks.

Second, the theory highlights the long-term restrictions on the model that will be used to identify some interesting linear combinations of the above-mentioned disturbances. Later, in section III, we will use these identifying restrictions to empirically evaluate the relative importance of world shocks versus different types of country-specific shocks in explaining international growth, cyclical fluctuations and comovements.

We should emphasize that the structural model presented here is to be regarded as applicable only in the long run. A full structural model is not specified because we do not wish to highlight particular economic mechanisms as being more important a priori than others in the short run, which we would have to do in order to make a short-run structural model tractable. Our empirical strategy is general enough to let the data decide which economic mechanisms are more important in the short run. Of course, the implementation of our strategy does require some identifying restrictions. These will be the restrictions from our long-run model which, we argue, are relatively uncontroversial, as well as an assumption about the information structure the plausibility of which we hope to be able to convince the reader.

II.1. Long-Run Model without Money

Consider a world economy which consists of two countries each of which consumes two goods. There is complete specialization in production with the domestic country producing good h labelled the home good, and the foreign country producing good f, labelled the foreign good. We assume an integrated world capital market so that there is one uniform world real rate of interest.

It is also assumed that long-run neutrality of money holds. Thus, in the very long run, real variables are determined independently of the monetary sector. However, in the empirical work we will allow for money to affect real economic activity in the short-to-medium run with the mechanisms through which this effect takes place being relatively unrestricted. To motivate this empirical work, a section which extends our theoretical long-run real model to incorporate money is also included.

Output

The output of the domestic country expressed in units of the domestic composite good (which essentially is real GNP of the home country), Y_{ht}, is given by:

$$\ln Y_{ht} = \bar{Y}_h + \alpha_h \ln N_{ht} + \ln\left(\frac{P_{ht}}{P_t}\right) + u_t$$

where N_{ht} is the domestic country's labor input, P_{ht} is the price of good h in domestic currency units, P_t is the aggregate price level in the domestic country, u_t is an error term which represents a world supply shock and $\bar{Y}_h$, α_h are fixed parameters. This output specification is consistent with Cobbb-Douglas technology with labor as the only input. The relative price, $\left(\frac{P_{ht}}{P_t}\right)$ appears to convert output into units of the aggregate good. For simplicity, the capital input has been ignored. Our conjecture is that the long-run predictions of the model are not sensitive to this assumption.

In order to allow the long-run behavior of labor and production to be stochastic, the labor input, N_{ht}, and the error term in the production function, u_t, are modelled as follows:

$$\ln N_{ht} = \ln N_{h,t-1} + \bar{N}_h + \tau_{ht}$$

$$u_t = u_{t-1} + \tau_t$$

where τ_t, τ_{ht} are zero-mean, serially uncorrelated and independent error terms. The shock τ_t is a world productivity disturbance and τ_{ht} is a country-specific supply shock. $\bar{N}_h$ is a fixed parameter representing drift in labor supply. The domestic country's output growth can now be written as:

$$\Delta y_{ht} = \bar{y}_h + \Delta q_{ht} + (\tau_t + \alpha_h \tau_{ht}) \qquad (1)$$

where $y_{ht} \equiv \ln Y_{ht}$, $q_{ht} \equiv \ln p_{ht} \equiv \ln \left(\frac{P_{ht}}{P_t}\right)$, $\bar{y}_h \equiv \alpha_h \bar{N}_h$ and Δ is the first difference operator.

Similarly, the growth rate of the foreign country's output expressed in units of the domestic country composite good can be written as:

$$\Delta y_{ft} = \bar{y}_f + \Delta q_{ft} + \tau_t + \alpha_f \tau_{ft} \tag{2}$$

where $y_{ft} \equiv \ln Y_{ft}$, Y_{ft} = output of good f expressed in domestic country aggregate units, $q_{ft} \equiv \ln p_{ft} \equiv \ln\left(\frac{e_t P^*_{ft}}{P_t}\right)$ [where P^*_{ft} = price of good f in the foreign country's currency units, and e_t = nominal exchange rate (domestic currency units per unit foreign currency)], τ_{ft} = shock to foreign country's labor input and α_f, $\bar{y}_f$ are fixed parameters.

Private GNPs and the Government Sector

The government in each country purchases goods and services from the private sector. These purchases are exogenously given and assumed to be financed by lump-sum taxation for simplicity, so that there are no tax rate shocks in our model. The government's actions do not affect the marginal decisions of private agents and therefore the benefits, if any, of government spending are assumed to affect utility in a separable manner. It should be possible to extend our model to allow for government purchases to substitute for private consumption and also to enter the production function directly. We also take the government's budget to be balanced in the long run.

Domestic private GNP, Y^P_{ht}, defined as aggregate output less aggregate government purchases of goods and services is given by:

$$Y^P_{ht} \equiv Y_{ht} - G_{ht} = (1-g_{ht})Y_{ht}$$

where G_{ht} is aggregate purchases of domestic goods and services by the domestic government and $g_{ht} \equiv \frac{G_{ht}}{Y_{ht}}$ represents the size of the domestic government. In setting g_{ht}, the domestic government behaves according to:

$$\ln(1-g_{ht}) = \ln(1-g_{h,t-1}) - \eta_{ht} - \phi_h \eta_{ft}$$

subject to the constraint $0 < g_{ht} < 1$. The disturbance term η_{ht} may be regarded as a permanent exogenous shock to the size of the government and $\phi_h \eta_{ft}$ as the feedback reaction by the domestic fiscal authority in response to an exogenous shock to the size of the foreign country's government. Thus $\phi_h > 0$ implies that if the foreign country expands the government sector, the domestic country reacts by doing likewise. The disturbance terms η_{ht}, η_{ft} are assumed to be zero mean, serially uncorrelated and independent.

Given the government's behavior described above, the growth rate of private GNP in the domestic country can be written as:

$$\Delta y^P_{ht} = \bar{y}_h + \Delta q_{ht} + \tau_t + \alpha_h \tau_{ht} - \eta_{ht} - \phi_h \eta_{ft} \tag{3}$$

where $\quad y^P_{ht} \equiv \ln Y^P_{ht}$.

Along similar lines the growth rate of the foreign country's private GNP in units of the <u>domestic</u> composite good can be expressed as:

$$\Delta y^P_{ft} = \bar{y}_f + \Delta q_{ft} + \tau_t + \alpha_f \tau_{ft} - \eta_{ft} - \phi_f \eta_{ht} \tag{4}$$

with the variables for the foreign country defined in an analogous manner to those of the domestic country.

<u>Consumption</u>

In choosing the desired consumption of each good, the representative agent in the domestic country solves the following maximization problem.

$$\max \quad E_t \sum_{j=0}^{\infty} \left(\frac{1}{1+\rho}\right)^j (\psi_{h,t+j} \ln C_{h,t+j} + \psi_{f,t+j} \ln C_{f,t+j})$$

subject to the lifetime budget constraint:

$$\sum_{j=0}^{\infty} D_j \, (Y^P_{h,t+j} - p_{h,t+j}C_{h,t+j} - p_{f,t+j}C_{f,t+j}) = 0$$

where $C_h(C_f)$ is the domestic representative agent's desired consumption of the domestic (foreign) good, α_h, α_f are preference parameters allowed to vary over time, E_t is the rational expectations operator conditional information available at time t, ρ is the time-preference rate and D_j is a discount rate defined as $D_j \equiv \prod_{t}^{t+j-1} \left(\frac{1}{1+r_i}\right)$, $D_0 = 1$ for period 0, and $D_j = \prod_{k=0}^{j-1} \left(\frac{1}{1+r_k}\right)$ for $j \geq 1$, with r_k representing the anticipated world real interest rate between k and k+1 in units of the domestic aggregate good. Recall the $p_h(p_f)$ represents the relative price of the home (foreign) good in units of the domestic aggregate good, so that $p_h \equiv \frac{P_h}{P}$ $\left(p_f \equiv \frac{eP^*_f}{P}\right)$.

We assume that the shocks τ_t, τ_{ht}, τ_{ft}, η_{ht}, η_{ft} (and the permanent preference shocks to be introduced below) become known to economic agents one period in advance in order to obtain explicit reduced-form solutions from an optimization framework. That is, all disturbance terms that affect economic variables <u>permanently</u> are anticipated one period before their effect on the economy starts to take place ($E_t\tau_{t+1} = \tau_{t+1}$, etc.). We discuss the plausibility of this assumption later, but at this stage should point out that we use the assumption only to give an <u>explicit microfoundation</u> to our long-run model.

Under the above assumption, the first-order necessary conditions for consumption in the domestic country, after solving for the Lagrange multiplier, are:

$$\frac{p_{h,t+1}\, C_{h,t+1}}{p_{ht}\, C_{ht}} = \frac{1+r_t}{1+\rho}\, \frac{\psi_{h,t+1}}{\psi_{ht}} \; ; \quad \frac{p_{f,t+1}\, C_{f,t+1}}{p_{ft}\, C_{ft}} = \frac{1+r_t}{1+\rho}\, \frac{\psi_{f,t+1}}{\psi_{ft}} \tag{5}$$

If the structure of preferences in the foreign country is exactly the same as the domestic country, we have analogous first-order conditions for the representative agent in the foreign country:

$$\frac{p_{h,t+1}\, C^*_{h,t+1}}{p_{ht}\, C^*_{ht}} = \frac{1+r_t}{1+\rho}\, \frac{\psi_{h,t+1}}{\psi_{ht}} \; ; \quad \frac{p_{f,t+1}\, C^*_{f,t+1}}{p_{ft}\, C^*_{ft}} = \frac{1+r_t}{1+\rho}\, \frac{\psi_{f,t+1}}{\psi_{ft}} \tag{6}$$

where the asterisk is used to denote foreign consumptions. These first-order conditions have the standard interpretation, stating that the ratio of discounted marginal utilities equals the relative intertemporal price.

Next we turn to a discussion of the information structure we have imposed, which is to assume that $E_t \tau_{t+1} = \tau_{t+1}$ and analogous assumptions with respect to other disturbances which alter the long-run path of the economy. These assumptions are not as restrictive as it might first appear. First, with respect to technological innovations it is not implausible to postulate that new technology becomes known well before it can be implemented to produce new output. Second, real business cycle theories often involve the time-to-build hypothesis with respect to all inputs including labor (see for example Long and Plosser [1983]) to make these models tractable. In such a set-up the assumption that <u>permanent</u> shocks to input productivities take one period to get reflected in output movements can be defended. Finally, the information structure assumed applies only to <u>permanent</u> shocks and does not preclude unanticipated shocks from having contemporaneous effects on output as long as these shocks are stationary. Since we are interpreting our solutions as applying only in the long-run, our procedure can be thought of as having

replaced these stationary shocks by their long-run mean values of zero. For example, the possibility that an unanticipated outbreak of war will immediately affect the productivity of previously chosen inputs is not ruled out, provided the war is not expected to last forever.[3]

Market-Clearing Solutions:

To close the model we need the markèt-clearing conditions for each good, which are given below:

$$Y^P_{ht} = p_{ht}(C_{ht} + C^*_{ht}) \tag{7}$$

$$Y^P_{ft} = p_{ft}(C_{ft} + C^*_{ft}) \tag{8}$$

We also postulate that the preference parameters follow random walk behavior to allow for permanent shocks to the demand for each good. Specifically,

$$\ln \psi_{ht} = \ln \psi_{h,t-1} + \varepsilon_{ht}$$

$$\ln \psi_{ft} = \ln \psi_{f,t-1} + \varepsilon_{ft}$$

where ε_{ht}, ε_{ft} are zero-mean, serially uncorrelated, independent error terms.

Finally, before setting out the solutions, it is useful to point out the relationship between p_{ht}, p_{ft} and the aggregate domestic price level P_t. Suppose the domestic price level P_t can be written as $P_t = P_{ht}^{1-a_f}(e_t P^*_{ft})^{a_f}$, where a_f is the weight given to imported goods in forming the aggregate price level. Recall that $q_{ht} \equiv \ln p_{ht} = \ln \frac{P_{ht}}{P_t}$ and $q_{ft} = \ln p_{ft} = \ln\left(\frac{e_t P^*_{ft}}{P_t}\right)$. Given the definition of P_t it follows that $q_{ht} = -\frac{(1-\gamma)}{\gamma} q_{ft}$, where $\gamma \equiv (1-a_f)$. Then if a_f is assumed to be known, we need solve for only one of the two relative prices q_{ht} and q_{ft}.

Using the specification for preference and productivity shocks, the output equations (1)-(4), the arbitrage conditions (5)-(6), the market-clearing conditions (7) and (8) and the relationship between q_{ft} and q_{ht} discussed above, the solutions for the endogenous variables are given by:

$$\Delta q_{ft} = \gamma(\bar{y}_h - \bar{y}_f) + \gamma\alpha_h\tau_{ht} - \gamma\alpha_f\tau_{ft} - \gamma(1-\phi_f)\eta_{ht} + \gamma(1-\phi_h)\eta_{ft} - \gamma(\varepsilon_{ht} - \varepsilon_{ft}) \tag{9}$$

$$\Delta y_{ht} = \gamma\bar{y}_h + (1-\gamma)\bar{y}_f + \tau_t + \gamma\alpha_h\tau_{ht} + (1-\gamma)\alpha_f\tau_{ft} + (1-\gamma)(1-\phi_f)\eta_{ht} - (1-\gamma)(1-\phi_h)\eta_{ft} + (1-\gamma)(\varepsilon_{ht} - \varepsilon_{ft}) \tag{10}$$

$$\Delta y^P_{ht} = \gamma\bar{y}_h + (1-\gamma)\bar{y}_f + \tau_t + \gamma\alpha_h\tau_{ht} + (1-\gamma)\alpha_f\tau_{ft} - [\gamma(1-\phi_f) + \phi_f]\,\eta_{ht} - [(1-\gamma)(1-\phi_h) + \phi_h]\eta_{ft} + (1-\gamma)(\varepsilon_{ht} - \varepsilon_{ft}) \tag{11}$$

$$\Delta y_{ft} = \gamma\bar{y}_h + (1-\gamma)\bar{y}_f + \tau_t + \gamma\alpha_h\tau_{ht} + (1-\gamma)\alpha_f\tau_{ft} - \gamma(1-\phi_f)\eta_{ht} + \gamma(1-\phi_h)\eta_{ft} - \gamma(\varepsilon_{ht} - \varepsilon_{ft}) \tag{12}$$

$$\Delta y^P_{ft} = \gamma\bar{y}_h + (1-\gamma)\bar{y}_f + \tau_t + \gamma\alpha_h\tau_{ht} + (1-\gamma)\alpha_f\tau_{ft} - [\gamma(1-\phi_f) + \phi_f]\eta_{ht} - [(1-\gamma)(1-\phi_h)+\phi_h]\,\eta_{ft} - \gamma(\varepsilon_{ht} - \varepsilon_{ft}) \tag{13}$$

$$\Delta n_{ht} = \bar{N}_h + \tau_{ht} \tag{14}$$

$$\Delta n_{ft} = \bar{N}_f + \tau_{ft} \tag{15}$$

$$r_{t-1} = \rho + \gamma\bar{y}_h + (1-\gamma)\bar{y}_f + \tau_t + \gamma\alpha_h\tau_{ht} + (1-\gamma)\alpha_f\tau_{ft} - [\gamma(1-\phi_f) + \phi_f]\eta_{ht} - [(1-\gamma)(1-\phi_h) + \phi_h]\eta_{ft} - \gamma\varepsilon_{ht} - (1-\gamma)\varepsilon_{ft} \tag{16}$$

Interpretation of Long-Run Paths

The equations (9) - (16) have a straightforward interpretation which the following discussion brings out. Consider a positive, permanent world supply shock ($\tau_t > 0$). Since productivity is higher, outputs of both good rise, and if the fiscal authorities do not change the size of government in response,

private GNPs also rise. The relative prices of the home (q_{ht}) or foreign good (q_{ft}) do not change, because the supply shock is common to both goods. By assumption, a productivity disturbance occurring at time t was anticipated at time t-1, so that the expected real interest rate between t-1 and t, (r_{t-1}), rises.

Next we turn to a country-specific input productivity shock (say $\tau_{ht} > 0$). This has a direct effect on output of $\alpha_h \tau_{ht}$ where the parameter α_h reflects the marginal productivity of labor in the home country. However due to excess supply of the home good relative to the foreign good, there is also an adverse terms of trade effect for the domestic country, leading to a downward revaluation of home output so that the net effect on output is less than $\alpha_t \tau_{ht}$ (since $0 < \gamma < 1$). For the foreign country, the terms of trade movement is favorable leading to an upward revaluation of this output expressed in domestic country aggregate units. Once again private GNPs change by the same amount and in the same direction as actual GNPs. There is also a rise in r_{t-1} because the supply shock was anticipated at t-1. The intuition behind a permanent disturbance to the foreign country's labor supply ($\tau_{ft} > 0$) is symmetric to the case discussed above.

The third types of shocks to consider are preference shocks. Suppose $\varepsilon_{ht} - \varepsilon_{ft} > 0$. This creates excess demand for good h relative to good f and leads to a rise in the relative price of h and a fall in the relative price of f. The favorable terms of trade effect for the home country causes a rise in y_{ht} and y^P_{ht} and the unfavorable terms of trade movement for the foreign country causes y_{ft} and y^P_{ft} to fall. Since ε_{ht}, ε_{ft} are anticipated demand shocks they will cause the expected real interest rate between t-1 and t to fall with the effects being different for ε_{ht} and ε_{ft} because r_{t-1} is defined in units of the domestic good.

Finally suppose there is a domestic fiscal policy shock and the domestic fiscal authority increases the size of the government sector ($\eta_{ht} > 0$). The direct effect of this is to decrease private GNP (y^P_{ht}) one to one. However, this will, in general, also tend to create excess demand for the home good relative to the foreign good and therefore improve the domestic country's terms of trade. This, in turn, causes the real value of domestic output (y_{ht}) to go up so that the net negative effect on private domestic GNP is less than one to one. This terms of trade effect, of course, decreases the real value of the foreign country's total and private GNP. The extent to which there is a terms of trade effect with the accompanied revaluations of outputs depends on how the foreign fiscal authority reacts in response to the actions of the domestic fiscal authority (that is, on the magnitude of ϕ_f). If there is full retaliation and the foreign government reacts by expanding its government sector one to one ($\phi_f = 1$), then there are no relative price effects and consequently no effects on domestic or foreign total outputs. Since η_{ht} is an anticipated (at time t-1) future demand shock the real interest rate, r_{t-1}, falls. The effects of exogenous foreign fiscal policy changes ($\eta_{ft} > 0$) can be analyzed in an analogous manner.

Transformed Long-Run Model

It is difficult to form measures of the ex ante world real interest rate. Also, since our foreign country is going to be an aggregate of many countries, data limitations prevent us from obtaining a good measure of the foreign labor input (η_{ft}). Therefore, anticipating the empirical work to follow, our long-run model without money can be thought of as consisting of the observed variables Δq_{ft}, Δy_{ht}, Δy^P_{ht}, Δy_{ft}, Δy^P_{ft}, Δn_{ht} behaving according to equations (9) - (14). The shocks driving the long-run path of these variables are τ_t, τ_{ht}, τ_{ft}, η_{ht}, η_{ft}, ε_{ht}, ε_{ft}.

Although the system derived above imposes cross-equation restrictions on the effects of the various shocks on the endogenous variables, as the model stands, all of the shocks themselves are not separately identified. However, some linear combinations of the shocks can be identified by writing down a transformation of the original model in which the transformed variables and shocks still have a natural economic intèrpretation. The transformed system is:

$$\begin{bmatrix} \Delta n_{ht} \\ \Delta y_{ht} - \Delta q_{ht} \\ \Delta y_{ft} - \Delta q_{ft} \\ (\Delta y^P_{ht} - \Delta q_{ht}) - (\Delta y^P_{ft} - \Delta q_{ft}) \\ \Delta q_{ft} \end{bmatrix} = \begin{bmatrix} \bar{N}_h \\ \bar{y}_h \\ \bar{y}_f \\ \bar{y}_h - \bar{y}_f \\ \gamma(\bar{y}_h - \bar{y}_f) \end{bmatrix}$$

$$+ \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \alpha_h & 1 & 0 & 0 & 0 \\ 0 & 1 & \alpha_f & 0 & 0 \\ \alpha_h & 0 & -\alpha_f & -1 & 0 \\ \gamma\alpha_h & 0 & -\gamma\alpha_f & -\gamma & -\gamma \end{bmatrix} \begin{bmatrix} \tau_{ht} \\ \tau_t \\ \tau_{ft} \\ (1-\phi_f)\eta_{ht} - (1-\phi_h)\eta_{ft} \\ \varepsilon_{ht} - \varepsilon_{ft} \end{bmatrix} \qquad (18)$$

The interpretation of the transformed variables is as follows.

$\Delta y_{ht} + \Delta y_{ht} - \Delta q_{ht} = \frac{1-\gamma}{\gamma} \Delta q_{ft}$ is the growth rate of the domestic output expressed in units of the home good (good h) rather than in units of the domestic composite good, which was the case in the untransformed system. Similarly $\Delta y_{ft} - \Delta q_{ft}$ is the growth rate of foreign output expressed in units of the foreign good (good f). $\Delta y^P_{ht} - \Delta q_{ht}) - (\Delta y^P_{ft} - \Delta q_{ft})$ is the growth rate of private domestic output in units of good h relative to private foreign output in units of good f. The transformed shocks are $\varepsilon_{ht} - \varepsilon_{ft}$, which has a direct interpretation as a relative preference shock, and $(1-\phi_f)\eta_{ht}-(1-\phi_h)\eta_{ft}$ which can be interpreted as a relative fiscal shock after taking into account the other country's feedback.

The matrix premultiplying the vector of shocks in (18), which we shall denote by C(1), is lower triangular so that enough long-run restrictions have been imposed to identify the domestic and foreign labor supply shocks (τ_{ht}, τ_{ft} respectively), the world supply shock (τ_t), the relative fiscal policy shock $[(1-\phi_f)\eta_{ht} - (1-\phi_h)\eta_{ft}]$ and the relative preference shock ($\varepsilon_{ht}-\varepsilon_{ft}$). In terms of the economics these restrictions may be summarized as follows. Labor supplies are exogenously given in the long run. Given that the domestic labor input is observed, this identifies τ_{ht}. Outputs are completely supply determined in the long-run being influenced only by own labor input shock and world supply shock. The behavior of domestic output over the long-run then identifies τ_t, given τ_{ht}. Although the foreign labor supply is not directly observed, given τ_t, the behavior of foreign output allows us to recover τ_{ft}. The identification of τ_{ht}, τ_{ft} (and the fact that the ratio of private GNPs in the two countries in appropriately defined units is not influenced by τ_t and the relative preference shock $\varepsilon_{ht} - \varepsilon_{ft}$) in turn identifies the relative fiscal shock. Finally, the other determinants the relative price of the

foreign good (τ_{ht}, τ_{ft}, the relative fiscal shock) fixed, the behavior of this price in the long-run identifies the relative preference shocks.

II.2. Introducing Money

Consider adding the following equations describing the behavior of money growth in the long run in each country.

$$\Delta m_{ht} = \pi_0 + \pi_1\tau_t + \pi_2\tau_{ht} + \pi_3\tau_{ft} + \pi_4(\eta_{ht} + \phi_h\eta_{ft}) + \pi_5(\eta_{ft} + \phi_f\eta_{ht}) + \pi_6\varepsilon_{ht} + \pi_7\varepsilon_{ft} + \pi_8 v_{ft} + v_{ht} \tag{19}$$

$$\Delta m_{ft} = \pi_0^* + \pi_1^*\tau_t + \pi_2^*\tau_{ft} + \pi_3^*\tau_{ht} + \pi_4^*(\eta_{ft} + \phi_f\eta_{ht}) + \pi_5^*(\eta_{ht} + \phi_h\eta_{ft}) + \pi_6^*\varepsilon_{ft} + \pi_7^*\varepsilon_{ht} + \pi_8^* v_{ht} + v_{ft} \tag{20}$$

where $m_{ht}(m_{ft})$ represents the log of money supply in the domestic (foreign) country, π's represent the domestic monetary authority's policy parameters, π^*'s are policy parameters chosen by the foreign monetary authority, and v_{ht}, v_{ft} are i.i.d. shocks representing the domestic and foreign money supply shock respectively. These equations may be regarded as the reaction functions of the monetary authorities in the two countries. Note that $\pi_4(\pi_4^*)$ may be interpreted as the domestic (foreign) monetary authority's reaction to own country changes in size of government and $\pi_5(\pi_5^*)$ their reactions to a change in the size of the other country's government sector.

Clearly some restrictions will be needed to identify the money shocks and also ensure that the identification restrictions discussed earlier still go through when money is introduced. The first restriction we impose is that long-run neutrality of money holds so that v_{ht} and v_{ft} have no effect on real variables in the very long run. This implies that the real model described above and the identification of the real shocks still go through.

However, since the real shocks appearing in the reaction functions (19) and (20) are not individually identified but only some linear combinations of them are known, monetary neutrality still does not allow us to recover the nominal shocks. Therefore, we also impose some long-run symmetry restrictions across (19) and (20). We assume that the monetary authorities' reaction to their own and the foreign country's fiscal changes are symmetric ($\pi_4 = \pi_4^*$, $\pi_5 = \pi_5^*$). Also the reactions to preference shocks to the good produced in their own country and the good produced in the other country are assumed symmetric ($\pi_6 = \pi_6^*$, $\pi_7 = \pi_7^*$).

We wish to emphasize three features about these restrictions. First, they are only <u>long-run</u> restrictions. No short-run symmetry restrictions on the money equations need be placed. Second, even in the long run, the symmetry is not assumed to be complete. Reactions of the two monetary authorities to τ_t are not necessarily equal and to τ_{ht}, τ_{ft} need not be symmetric. Third, even though long-run neutrality of money is imposed, in the short run money will be allowed to influence real variables with unrestricted dynamics.

Given these restrictions, the following equation can be added to the transformed real model given by (18).

$$\begin{aligned}\Delta m_{ht} - \Delta m_{ft} = {} & \phi_0 + \phi_1\tau_t + \phi_2\tau_{ht} + \phi_3\tau_{ft} + \phi_4[(1-\phi_f)\eta_{ht} - (1-\phi_h)\eta_{ft}] \\ & + \phi_5(\varepsilon_{ht} - \varepsilon_{ft}) + [(1-\pi_8)v_{ht} - (1-\pi_8^*)v_{ft}] \qquad (21)\end{aligned}$$

where $\phi_0 \equiv \pi_0 - \pi_0^*$, $\phi_1 \equiv \pi_1 - \pi_1^*$, $\phi_2 = \pi_2 - \pi_2^*$, $\phi_3 = \pi_3 - \pi_3^*$, $\phi_4 \equiv \pi_4 - \pi_5 = \pi_4^* - \pi_5^*$, $\phi_5 = \pi_6 - \pi_7 = \pi_6^* - \pi_7^*$. Given that τ_t, τ_{ht}, τ_{ft} and $(1-\phi_f)\eta_{ht} - (1-\phi_h)\eta_{ft}$ are already identified, (21) recovers the shock $(1-\pi_8)v_{ht} - (1-\pi_8^*)v_{ft}$, which can be interpreted as a relative money supply shock after taking into account the feedback reaction of the other country.

Long-Run Model with Money

In order to discuss the empirical methodology, which is done in the next section, it will be convenient to rewrite the complete long-run model with money in matrix form.

$$
\begin{bmatrix}
\Delta n_{ht} \\
\Delta y_{ht} - \Delta q_{ht} \\
\Delta y_{ft} - \Delta q_{ft} \\
(\Delta y^{P}_{ht} - \Delta q_{ht}) - (\Delta y^{P}_{ft} - \Delta q_{ft}) \\
\Delta q_{ft} \\
\Delta m_{ht} - \Delta m_{ft}
\end{bmatrix}
=
\begin{bmatrix}
\bar{N}_h \\
\bar{y}_h \\
\bar{y}_f \\
\bar{y}_h - \bar{y}_f \\
\gamma(\bar{y}_h - \bar{y}_f) \\
\phi_0
\end{bmatrix}
$$

$$
+
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
\alpha_h & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & \alpha_f & 0 & 0 & 0 \\
\alpha_h & 0 & -\alpha_f & -1 & 0 & 0 \\
\gamma\alpha_h & 0 & -\gamma\alpha_f & -\gamma & -\gamma & 0 \\
\phi_1 & \phi_2 & \phi_3 & \phi_4 & \phi_5 & 1
\end{bmatrix}
\begin{bmatrix}
\tau_{ht} \\
\tau_t \\
\tau_{ft} \\
(1-\phi_f)\eta_{ht} - (1-\phi_h)\eta_{ft} \\
\varepsilon_{ht} - \varepsilon_{ft} \\
(1-\pi_8)v_{ht} - (1-\pi_8^*)v_{ft}
\end{bmatrix}
\qquad (22)
$$

III. Empirical Analysis

In this section we estimate the model just described and present the relevant findings. We begin by discussing the empirical methodology we use to estimate the model and discuss the data used in this study.

III.1. Estimation Strategy

The theoretical model summarized in equation (22) is a multivariate time series model. It can be compactly written as:

$$X_t = C(L)\varepsilon_t \tag{23}$$

where X_t is the vector of dependent variables, ε_t is a vector of shocks, and C(L) is a moving average polynominal matrix which has the long-run restriction that C(1) be a lower triangular matrix. This representation for X_t is uniquely identified (Blanchard and Quah 1988).

The structural form of (23) can be written in VAR form:

$$A(L)X_t = \varepsilon_t \tag{24}$$

where A(L) is the inverse of C(L), and A(1) is thus a lower triangular matrix. In order to explicitly impose the long-run restriction of the model, we first note that:

$$\begin{aligned} A(L) &= [A(L) - A(1)L] + A(1)L \\ &\equiv \Delta A^*(L) + A(1)L. \end{aligned}$$

Using this, and denoting -A(1) = B, we can rewrite (24) as:

$$A^*(L)\Delta X_t = BX_{t-1} + \varepsilon_t \tag{25}$$

Direct estimation of (25) is inconvenient due to the restrictions imposed on both B and the variance of ε_t. We can exactly identify the system, however, by imposing the restrictions that B is lower triangular, and ε that the shocks in ε_t are mutually uncorrelated. These restrictions then allow us to estimate the system from its reduced form. To see this, let the reduced form be:

$$\Gamma(L)\Delta X_t = \Phi X_{t-1} + \eta_t \tag{26}$$

where $\Gamma(0)$, the leading coefficient matrix of $\Gamma(L)$, is an identity matrix, and Φ and $\mathrm{var}(\eta_t) \equiv \Omega$ are unrestricted nonsingular matrices. Note that (26) is equivalent to the VAR representation of X_t in levels only and can thus be estimated using OLS equation by equation.

We now establish the relationship between (25) and (26). First multiply the inverse of Φ to both sides of (26):

$$\Phi^{-1}\Gamma(L)\Delta X_t = X_{t-1} + \Phi^{-1}\eta_t \tag{27}$$

We can now recover (25) by multiplying both sides of (27) by the inverse of the Cholesky factor of $\Phi^{-1}\Omega\Phi^{-1'}$. Estimation of C(1) follows immediately, using the relation $C(1) = -B^{-1}$.

The coefficients of C(1) represent the long-run effects on the endogenous variable (in (22)) of the various shocks. We can then use this to derive impulse response functions, so that we can observe the effects of these shocks under each regime.

III.2 Data

The period under consideration is 1960:1 to 1986:4. Data for each country on GDP, government spending, exchange rates, implicit price deflators

and money stock are from OECD Main Economic Indicators. The data on hours and U.S. imports comes from the National Income and Product Accounts. U.K. money date is derived from Darby and Lothian et al. (1983) and from the Bank of England Quauterly Reports. For details, see appendix (to be added).

III.3. Results

We turn next to the estimation of the transformed model assuming that the moving average matrix polynominal C(1) (in (22)) is lower triangular and that all shocks, including domestic and foreign labor supply shocks ($TH = \tau_h$ and $TF = \tau_f$), the common world supply shock ($TW = \tau$), the relative fiscal policy shock ($SF = (1-\phi_f)\eta_h - (1-\phi_h)\eta_f$), the relative preference shock ($SP = \epsilon_h - \epsilon_f$) and the relative money supply shock ($SM = (1-\pi_8)v_h - (1-\pi_8^*)v_f$), are mutually independent. There are six transformed variables in (log) levels: domestic labor supply ($NH = n_h$), domestic output ($YHQH = y_h - q_h$), foreign output ($YFQF = y_f - q_f$), the difference in domestic and foreign private outputs ($YPHF = (y_h^p - q_h) - (y_f^p - q_f)$), the relative foreign price ($QF = q_f$) and the difference in domestic and foreign money stocks ($MHMF = m_h - m_f$). Under the aforementioned identifying restrictions, we can examine the long-run and the short-run effects of the six shocks on the first differences of the above transformed variables: DNH, $DYHQH$, $DYFQF$, $DYPHF$, DQF and $DMHF$, which in fact represent growth rates of the labor, output, price and money variables.

Univariate Analysis

We first plot the six transformed series both in (log) levels and in first differences (see figure 1). Since all foreign variables are expressed in U.S. units, they exhibit during the later period downward movements, which may seem counter intuitive at the first sight. The differences of these variables show high volatility during the post-1973 period: they are clearly not stationary. Thus it may be tempting to transform the variables in order to impose constant

variances. However, such a transformation is inappropriate since it distorts the structural meaning of the disturbances.

We instead estimate the VAR model directly, including dummy variables for both intercept and slope coefficients for the post-1973 period in order to account for potential structural change. Upon estimating the VAR model, it is immediately apparent that the variances of the residuals for the post-1973 period are significantly larger than those of the pre-1973 period. This is the case for the VAR model under each of the estimated lag structures, indicating higher volatility of the shocks under the floating exchange rate regime. As an example we present the plot of the residuals for the estimated VAR with lag length two in figure 2 in which RESA, RESB, RESC, RESD, RESE and RESF are the estimates of the six shocks: TH, TW, TF, SF, SP and SM, respectively. In particular, the shifts in volatility are clearly visible for RESC, RESD and RESF.

We thus correct this heteroskedasticity problem in estimating the VAR's. Specifically, for each of the six equations, we first calculate the ratio of the standard deviation of the residuals for the post-1973 period to that for the pre-1973 period. Then we multiply all the variables for the pre-1973 period by this ratio so that the residuals exhibit constant variance across the two periods. We are in effect estimating two different equations for the two periods. After determining the lag length with this specification, we shall later examine the redundancy of the dummies to test the stability of the system.

Determination of Lag Length

In order to determine the lag length, we rely on two measures: the Akaike Information Criterion (AIC) and the likelihood ratio (LR) test. In calculating the LR statistic, we have used the correction of the degrees of freedom suggested by Sims (1980). Table 1 presents the statistics for the VAR systems with lag lengths one through four. The AIC achieves its minimum when the length is two. The LR test also concludes the same: the LR statistics for lag length 3 versus two as well as four versus three are insignificant, while that for two versus one is significant at five percent significance level. We note that all the three LR statistics

are asymptotically χ^2 distributed with degrees of freedom 72 (the critical values are 90.53 and 101.88 for the sample sizes of 70 and 80, respectively). Both tests suggest that VARs with two lags are appropriate.

Test for Stability

We now investigate the possible structural changes due to the change in the exchange rate regime. First, we test whether the long-run responses of the system are the same for both periods. This amounts to testing for the significance of the slope dummies for the long-run coefficients, Φ, in equation (26). The LR statistic for this hypothesis turns out to be 31.61, which is asymptotically χ^2 distributed with 36 degrees of freedom (the critical values are 43.77 and 55.76 for the sample sizes of 30 and 40, respectively). Hence it appears that there has been no significant structural change in the long-run responses.

Given the same response of the system in the long-run, it is naturally interesting to test whether the short-run responses are the same. This is essentially the same test as above but includes both the long-run and the short-run slope dummies. The LR statistic is 82.42 and the five percent critical value for the test is greater than 90.53, the value for the sample size of 70. It follows that the response of the system, both in the long run and in the short run, exhibits no significant difference between the two sub-periods.

In considering possible structural shifts, the final hypothesis we want to examine is that the average growth rates have changed. This can be done technically by testing for the significance of both the slope and the intercept dummies. The LR statistic for this hypothesis is 90.69, which is insignificant compared with the 5% critical values 90.53 and 101.88 for the sample sizes of 70 and 80, respectively (the degrees of freedom for the statistic is 78). From these test results, we may therefore conclude that no significant structural change has occured due to the shift in exchange rate regimes, except the higher volatility in the post-1973 period than the previous period: the relationships between the variables have been basically the same, though noisier. In a recent study, Baxter and Stockman (1988) found similar results using a different approach from ours.

Estimating the Structural VAR Model

Up to this point, our analysis has been based on the reduced form VAR model, equation (26). We next turn to the estimation of the structural VAR model, equation (25). Employing our previous test results on structural changes, we exclude all the dummies from the model (but still allowing for the difference in variances of the shocks) in estimating the reduced form VAR. As a crude guide for validation of the reduced form VAR, we provide in figure 3 the autocorrelograms of the residuals. If any misspecification in dynamic structure exists, it should be visible in the autocorrelograms. In the figure, UPPER and LOWER represents the asymptotic 5% critical values and the autocorrelations of the residuals are represented by RHOA, RHOB, RHOC etc. (in the corresponding order of the six shocks). The autocorrelation coefficients seem to strongly indicate that there is no omitted dynamics in the system, although they are univariate measures. After the reduced form is estimated, conversion to the structural VAR model is carried out according to the procedure explained in section III.1. The estimated structural VAR is not reported. Instead, we shall later present the plots of the impulse responses.

The long-run impulse response coefficient C(1) is obtaind by inverting A(1) in equation (24), and is reported in table 2. Both country-specific labor supply shocks, TH and TF, have sizable impacts on growth rates of both domestic and foreign outputs. This finding assures the positive international transmission of supply shocks. It is somewhat contrary to the traditional Mundell-Flemming model in which negative transmission may occur. One possible interpretation of the positive transmission is international risk sharing, such as given by Cantor and Mark (1988) for example. Moreover, both labor supply shocks seem to have greater impacts on foreign than on domestic output. This may reflect the fact that in more advanced economies, (maginal) labor productivity is usually lower and hence output may not be very sensitive to shocks in production factors. As a consequence, the growth rate differential between domestic and foreign private outputs responds negatively to those shocks, as can be seen from the fourth row of the first and second columns in table 2. In other words, "when the

U.S. sneezes, Europe gets pneumonia." The money growth rate differential also has negative responses to these shocks as does that of private outputs. This seems consistent with the real business cycle model with endogenous money developed by King and Plosser (1984). Further, an increase of domestic supply resulting from a positive domestic labor supply shock creates an excess supply of domestic goods and hence increases the relative foreign price. On the other hand, the long-run effect of a foreign supply shock on the relative foreign price has a sign opposite to our theoretical prediction, but the magnitude seems marginal.

An increase in the world supply shock increases growth rates of both domestic and foreign outputs but affects the foreign one by more, 1.25 versus 0.33, as was the case for country-specific supply shocks. The negative response of the relative foreign price, -0.08, appears to originate from the positive response of the supply of foreign goods. The responses of the two differential variables, DYPQHF and DMHMF, to the world supply shock are similar to their responses to the country-specific supply shocks.

A one unit increase in the relative fiscal shock generates a negative wealth effect. This in turn reduces domestic private output and hence the growth rate differential in private outputs by 1.61 percentage points. This accords with Barro (1986) in which a permanent increase in government spending supresses private output. On the other hand, due to the international transmission of fiscal shocks, foreign private demand for goods decreases as well and the growth rate of the foreign price thus gets lower, as the estimate -0.34 indicates. A positive domestic preference shock, or equivalently a negative foreign preference shock, reduces the demand for foreign goods through the substitution of domestic goods. The relative foreign price consequently falls on average by 0.64 percentage points according to our estimate. To accomodate domestic good transactions, domestic money thus grows by 0.99 percentage points more than foreign money does. Finally, a positive relative money supply shock increases the differential in money growth rates, as standard macro textbook theory predicts. This magnitude is estimated to be 1.23.

Analysis of Impulse Responses

We next examine the dynamic effects of all demand and supply shocks on the real output, price and monetary variables through the impulse responses of the estimated model to each of the structural shocks. Figure 4 gives the responses of the growth rates of domestic labor supply (DNH), domestic output (DYH=DYHQH), foreign output (DYF=DYFQF+DQF), the rate of change of the relative foregn price (DQF), and the growth rate differentials between domestic and foreign private outputs (DYPHF) and money balances (DMHF) to shocks in country-specific labor supply (TH and TF), world supply (TW), relative fiscal policy (SF), relative preference (SP) and relative money supply (SM). We find that most of the responses peak in the first or the second quarter and damp essentially within 12 quarters.

In the short run, a one standard deviation increase in the domestic labor supply shock (TH) has a positive impact effect on the growth rate of domestic labor supply; this response peaks at 0.68% in the first quarter and the adjustment is essentially complete after 7 quarters. The same shock also generates a positive impact effect on the growth rates of domestic and foreign outputs and relative foreign price (through the creation of an excess supply of domestic goods). The adjustment of output variables to this shock is long and they gradually converge to their new long-run value. The response of foreign price growth rate peaks at 0.37% in the third quarter and the adjustment is essentially complete after 10 quarters. Although this domestic labor supply shock yields a positive impact effect on the growth rate differential in private output, its effect is negative after the first quarter. Again, this may be due to the relatively low (marginal) labor productivity of the U.S. and the short-run advantage of a positive labor shock is outweighed by unfavorable international competition in the long run. On the other hand, a positive foreign labor supply shock (TF) has a negative impact effect on domestic variables througn good substitution. After 3 or 4 quarters, the effect becomes positive due to production complementarity. The responses of foreign output growth and the two growth rate differentials (in private output and money balances) peak in the third quarter and adjust gradually to their new steady-state values. We find that the international

transmission of country-spcific supply shocks seems very strong. Moreover, the responses to labor shocks usually exhibit a long-swing adjustment, which correborates findings in Shapiro and Waston (1988) under a different structural setup.

A one standard deviation increase in the world supply shock (TW) has a greater impact effect on the growth rate of foreign output than that of domestic output (1.21% versus 0.27%). Consequently, this shock generates a -1.23% (-1.80%) impact effect on the growth rate differential in private outputs (money balances) and the adjustment is gradually toward the new long-run level after 9 (12) quarters. Further, the same shock, by creating an excess supply of foreign goods, depresses the rate of change of the relative foreign price by 0.32% in the first quarter and the adjustment is essentially complete after 12 quarters.

We now study the impacts of demand shocks. First, an increase in the (relative) foreign fiscal shock (-SF) has essentially a zero short-run effect on domestic variables. It generates an -0.27% impact effect on the growth rate of foreign output in the first quarter and then has positive effect afterwards. The direct crowding out effect of foreign government spending reduces the growth rate of foreign private output (relative to that of domestic private output) by 1.45% in the first quarter. The same shock also creates an excess demand for foreign goods and hence depresses the relative foreign price by 0.45% in the first quarter. Both responses of DYPHF and DQF are negative after the second quarter when the response of foreign output growth becomes positive, as a consequence of expansionary foreign fiscal policy.

Next, a one standard deviation increase in the (relative) foreign preference shock (-SP) has very weak short-run effect on domestic output. This shock results in a substitution of foreign goods for domestic goods and so, through the derived demand effect on home production, yields a -0.12% impact effect on the growth rate of domestic hours. The shock, by creating an excess demand for foreign goods, generates an 0.16% impact effect on the growth rate of foreign output; this response peaks at 0.39% in the second quarter and the adjustment is essentially complete after 7 quarters. The excess demand for foreign goods increases the rate of change of relative foreign price by 0.45% in the first quarter and this adjustment takes about 7

quarters to converge to the new long-run level. To accomodate the foreign good transactions, the growth rate of foreign money balances increases (relative to that of the domestic ones); the adjustment is gradual and essentially complete after 9 quarters.

Finally, a positive (relative) domestic money supply shock (SM) has very little short-run impact on domestic labor and output. This may be due to the cancellation of the positive real balance effect and the negative term of trade effect. Its effect on foreign output is, however, sizable. The response of the growth rate differential between domestic and foreign real money balances to this 1% relative money supply shock peaks at 0.97% in the first quarter and the adjustment is essentially complete after 9 quarters. This increase in the domestic money growth rate should increase domestic inflation and hence creates a negative impact effect on the relative foreign price, which peaks at 0.14% in the second quarter. The improvement of the term of trade increases the rate of foreign output growth by 0.48% in the first quarter and the growth rate differential in private outputs is accordingly reduced by 0.31%.

In summary, the speed of the adjustment of each of the variables to supply shocks (TH, TF and TW) is generally longer than that to demand shocks (SF, SP and SM). The speed of the adjustment of the foreign output growth rate and real money growth rate differential to each innovation is far slower than that of the rate of relative price change and the private output growth rate differential to the same innovation. The country-spcific supply shocks have relatively large impact effects on both output growth rates (and hence their effects on the rate of relative price change and the growth rate differentials are rather small). The world supply shock seems to have much greater impact on foreign output growth and hence it affects the two growth rate differentials very significantly. In contrast to supply shocks, both relative fiscal and preference shocks have greater impact on the rate of relative foreign price change and the private output growth differential, while the relative money supply shock affects the real money growth differential the most. Further, focusing on the changes of the private output differential and the relative price, it can be concluded that any international policy coordination is more likely to be monetary rather than fiscal if it does exist. Finally, most

of the responses of the transformed variables to the relative preference shock are faster than those to policy shocks (SF and SM).

Decompositions of Variance

We now perform the variance decomposition analysis of the above mentioned six-shock model and present the results in table 3.

(To be added.)

Notes

1. There have been simulation studies of the effects of exchange rate regimes in international transmission (e.g., Frankel and Dominguez). These papers use macroeconometric models to study the extent of transmission. There have been very few papers that actually estimate the effect of the regime switch.

2. An important difference between Baxter and Stockman (and other work in this area, e.g., Chan [1988]) and ourselves is that they use industrial production data while we look at output. This is due to our focus on a macroeconomic model. Previous work in this area has typically consisted of statistical analysis of data, rather than estimating a macroeconometric model.

3. More specifically our set-up is quite consistent with a production function represented by

$$\ln Y_{ht} = \bar{Y}_h + v_{ht} + u_t + w_t + \ln\left(\frac{P_{ht}}{P_t}\right)$$

where u_t is an <u>anticipated</u> permanent world productivity disturbance ($\Delta u_t = \tau_t$), v_{ht} is an <u>anticipated</u> permanent country specific supply disturbance ($\Delta v_{ht} = \alpha_h \tau_{ht}$) and w_t is a <u>stationary unanticipated</u> supply disturbance (either world or country-specific). As long as w_t is stationary with zero mean, $\Delta w_t = 0$ in the long run and our solutions will be a valid description of long-term behavior.

Table 1: AIC and LR Statistics

Lag Length	AIC
1	-2568.70
2	-2578.91
3	-2528.23
4	-2523.49

Lag Length	LR Statistic
4 vs. 3	74.19
3 vs. 2	60.18
2 vs. 1	116.74

Table 2: Estimates of the Long-run Model

Variable	Long-run reponse to a one unit increase in					
	TH	TW	TF	SF	SP	SM
DNH	1.20	0	0	0	0	0
DYHQH	0.98	0.33	0	0	0	0
DYFQF	1.50	1.25	1.22	0	0	0
DYPHF	-0.40	-0.79	-1.09	-1.61	0	0
DQF	0.77	-0.08	0.06	-0.34	-0.64	0
DMHF	-1.95	-1.70	-1.70	0.69	0.99	1.23

Figure 1: Transformed Endogenous Variables in Log Levels and First Differences

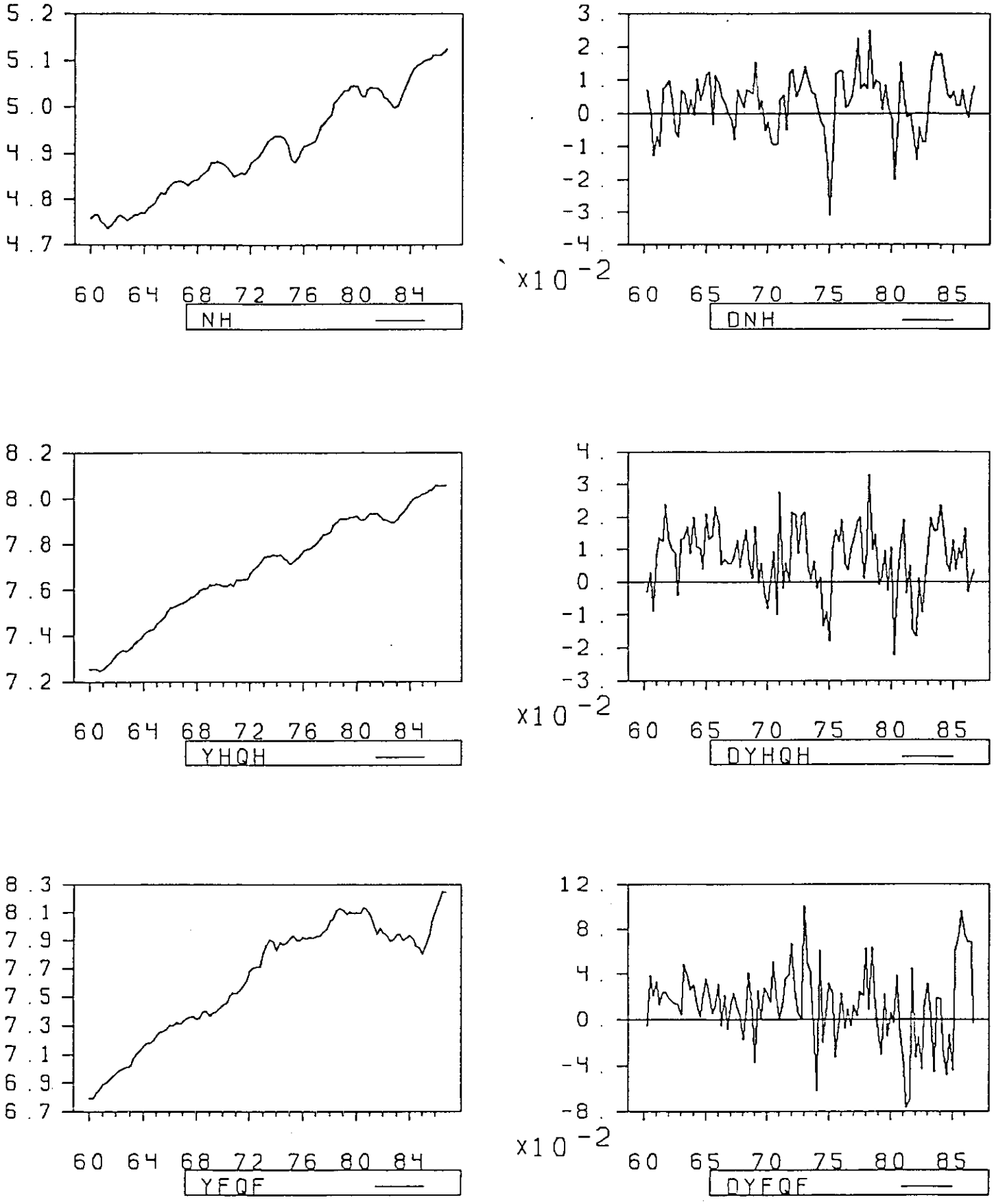


Figure 1: (continued)

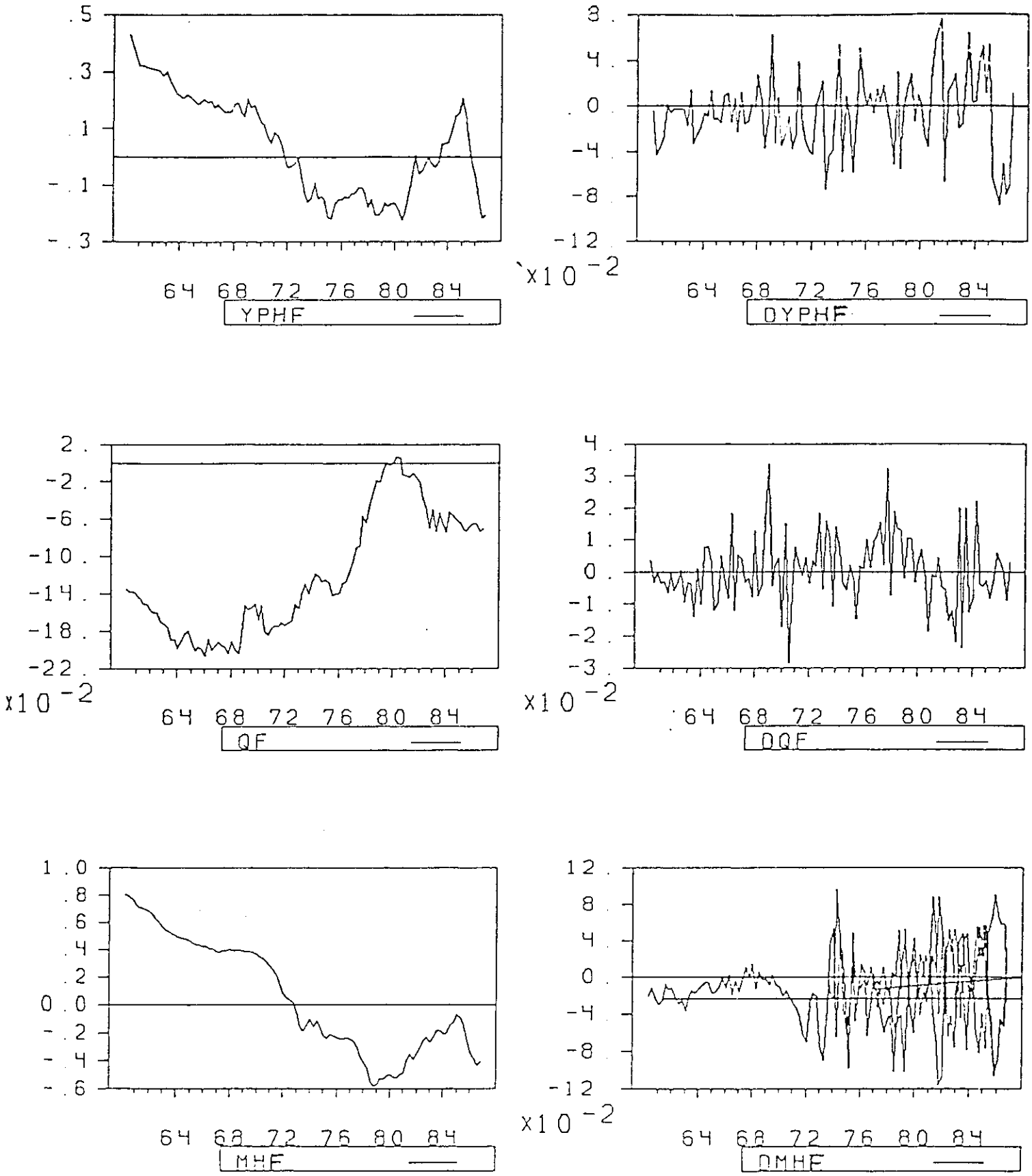


Figure 2: Residuals for the Estimated VAR with 2 Lags

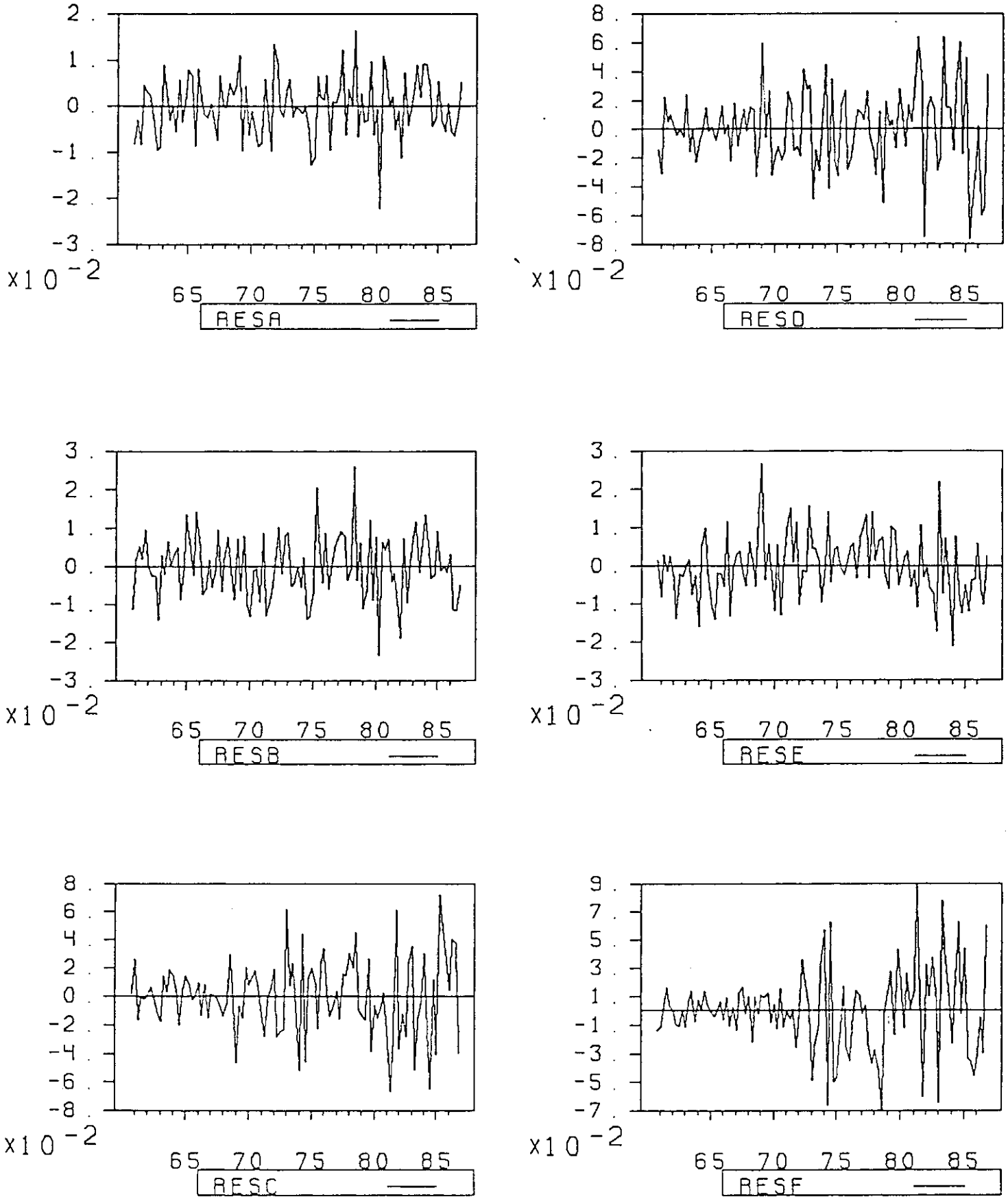


Figure 3: Autocorrelograms of Residuals

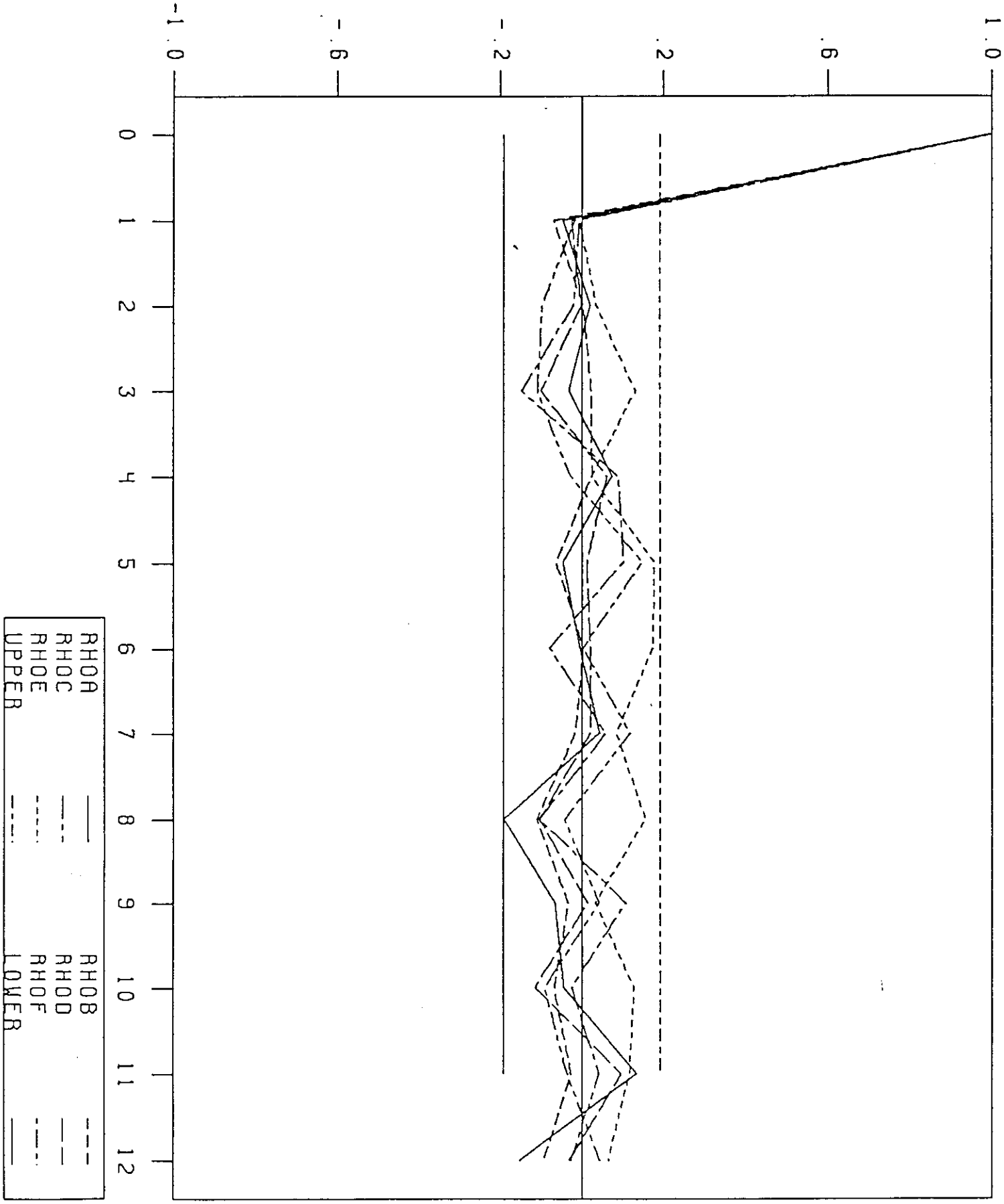


Figure 4: Impulse Reponses to TH Shock

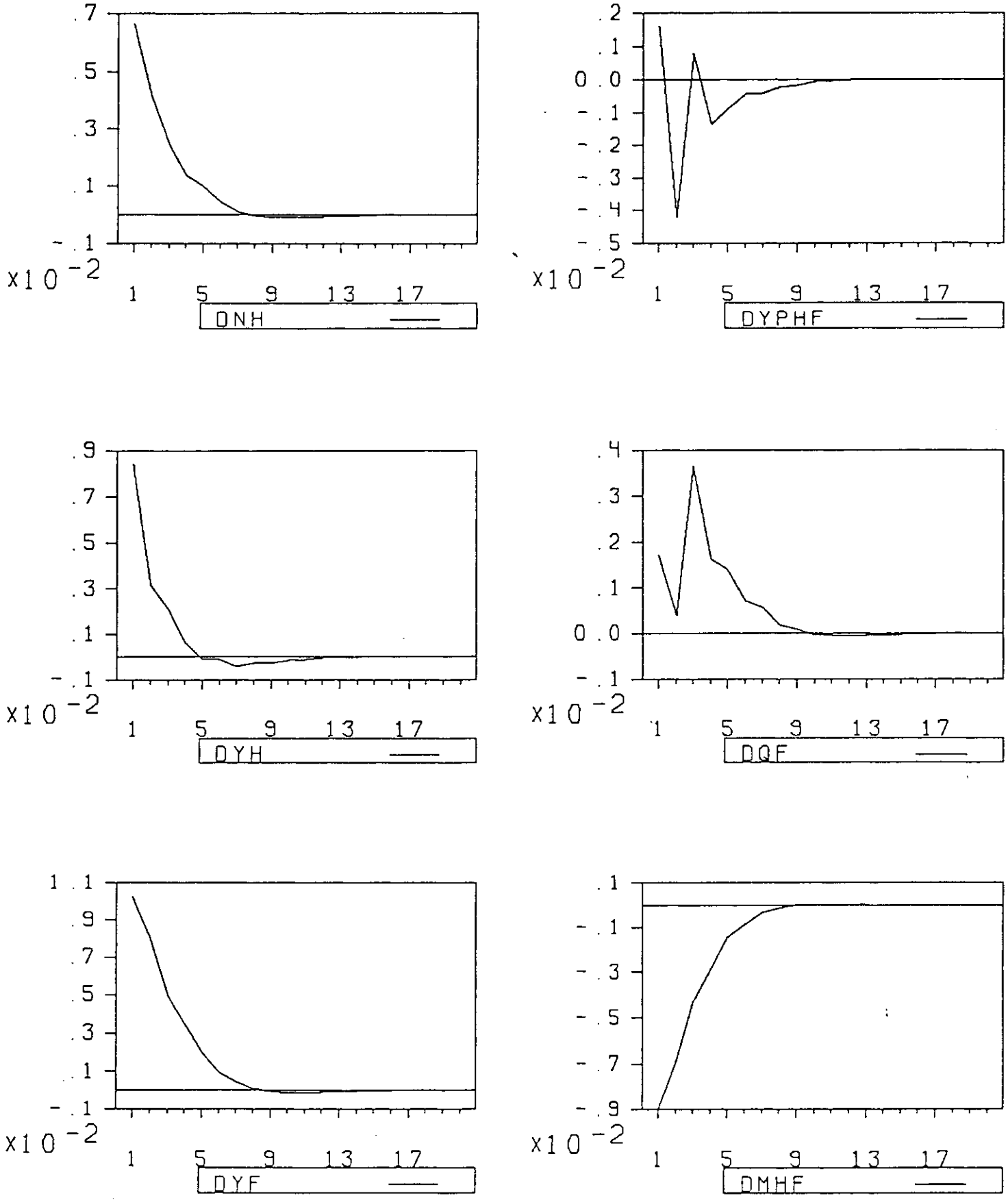


Figure 4: Impulse Reponses to TW Shock

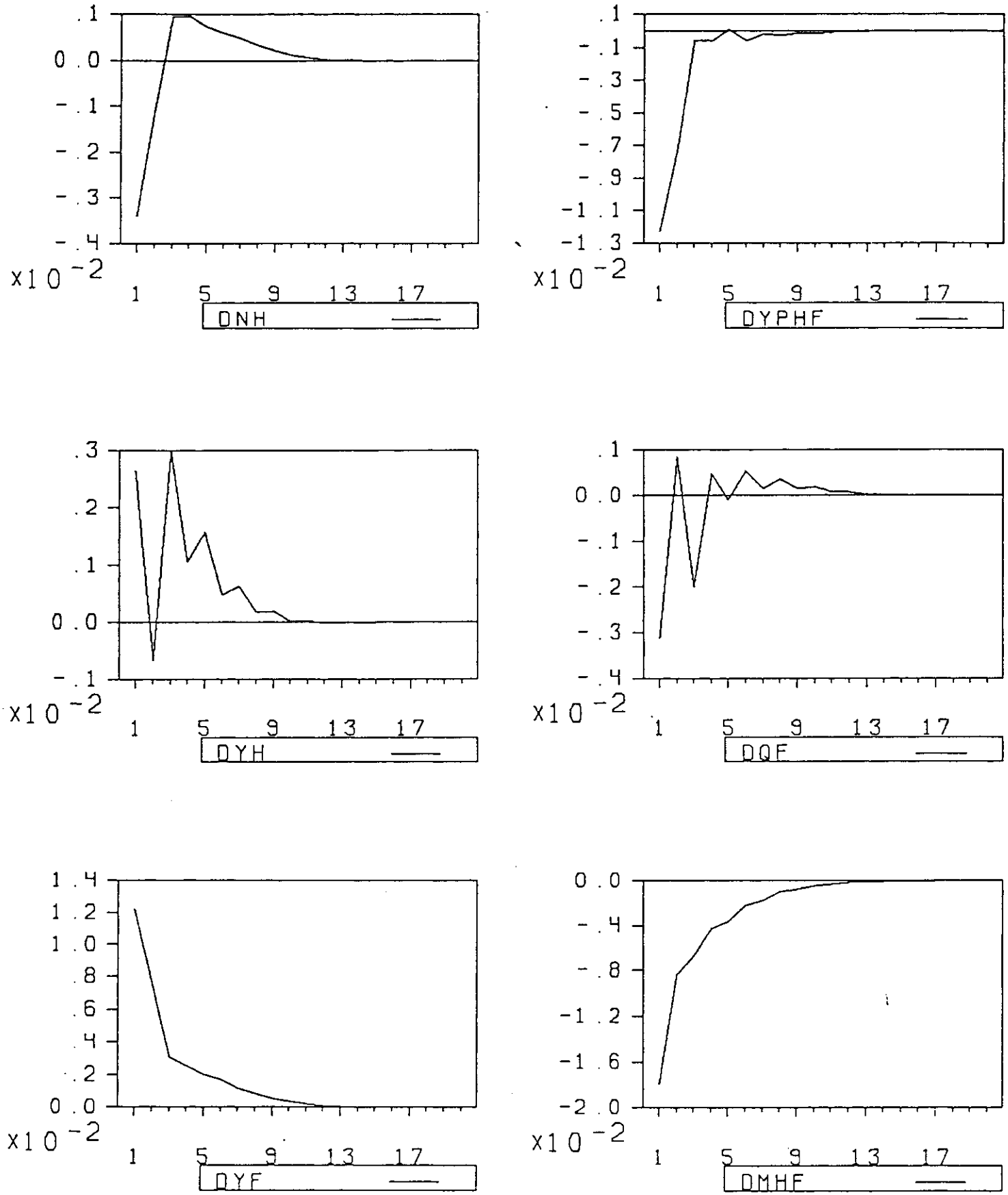


Figure 4: Impulse Responses to TF Shock

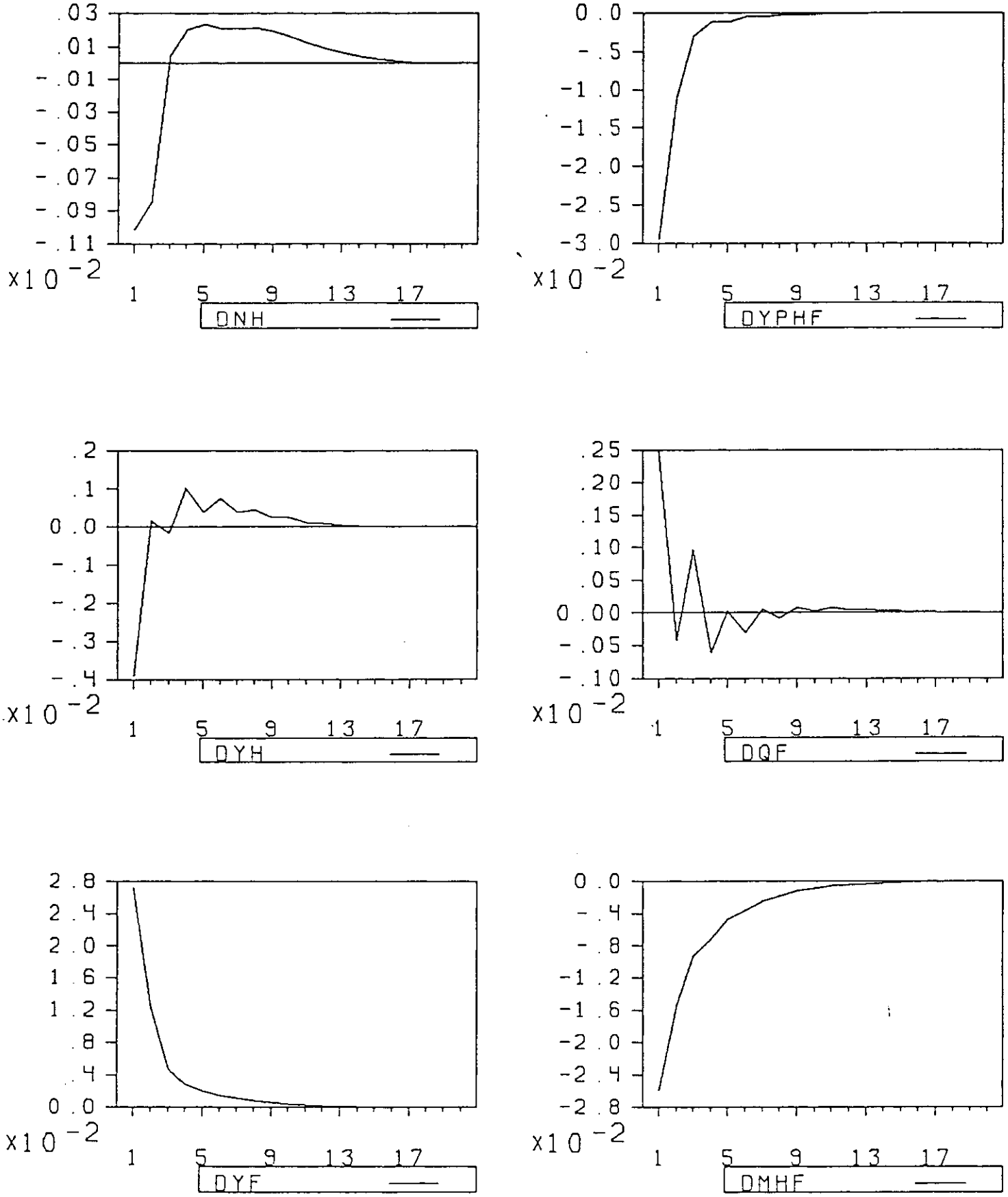


Figure 4: Impulse Reponses to -SF Shock

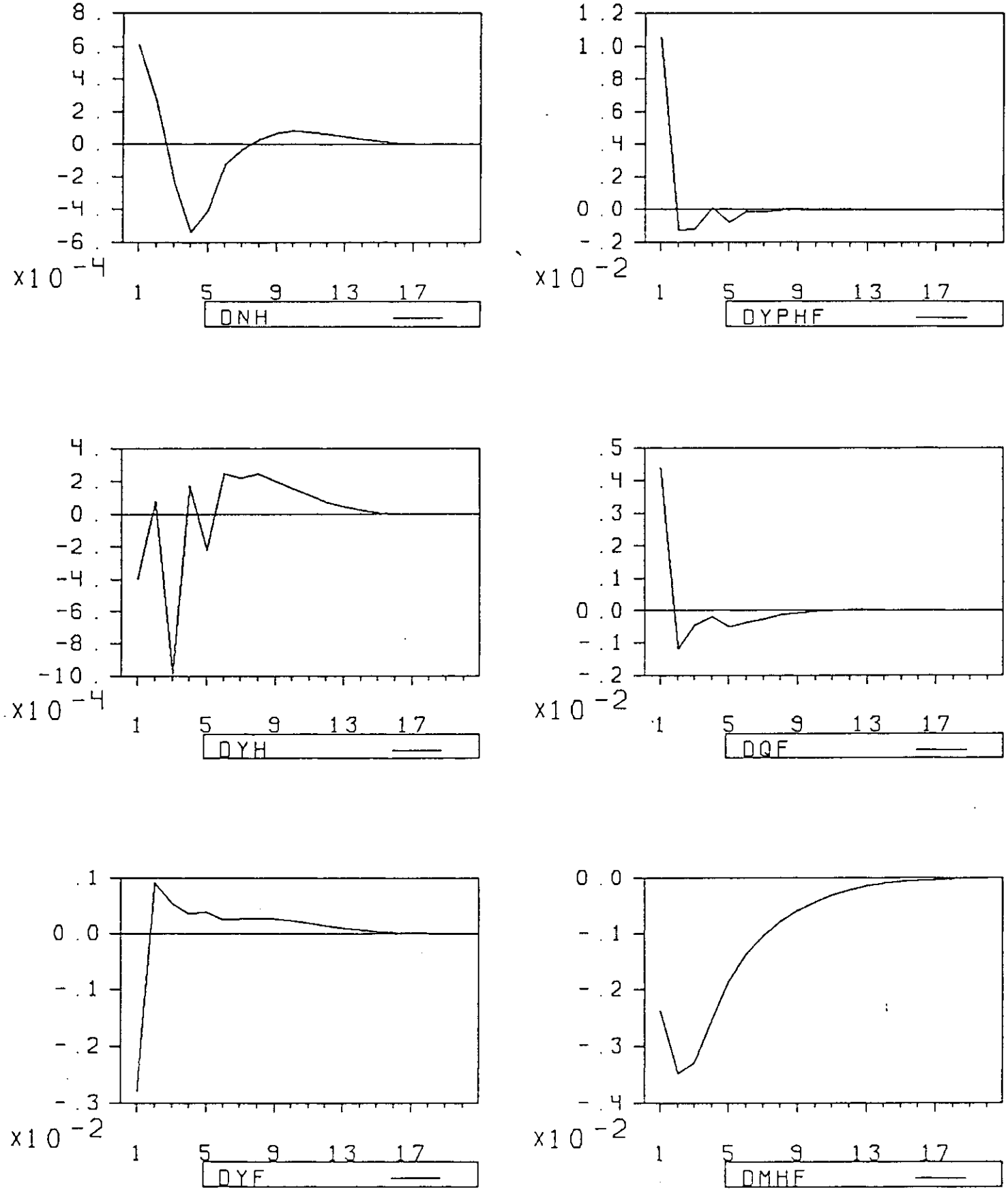


Figure 4: Impulse Responses to _SP Shock

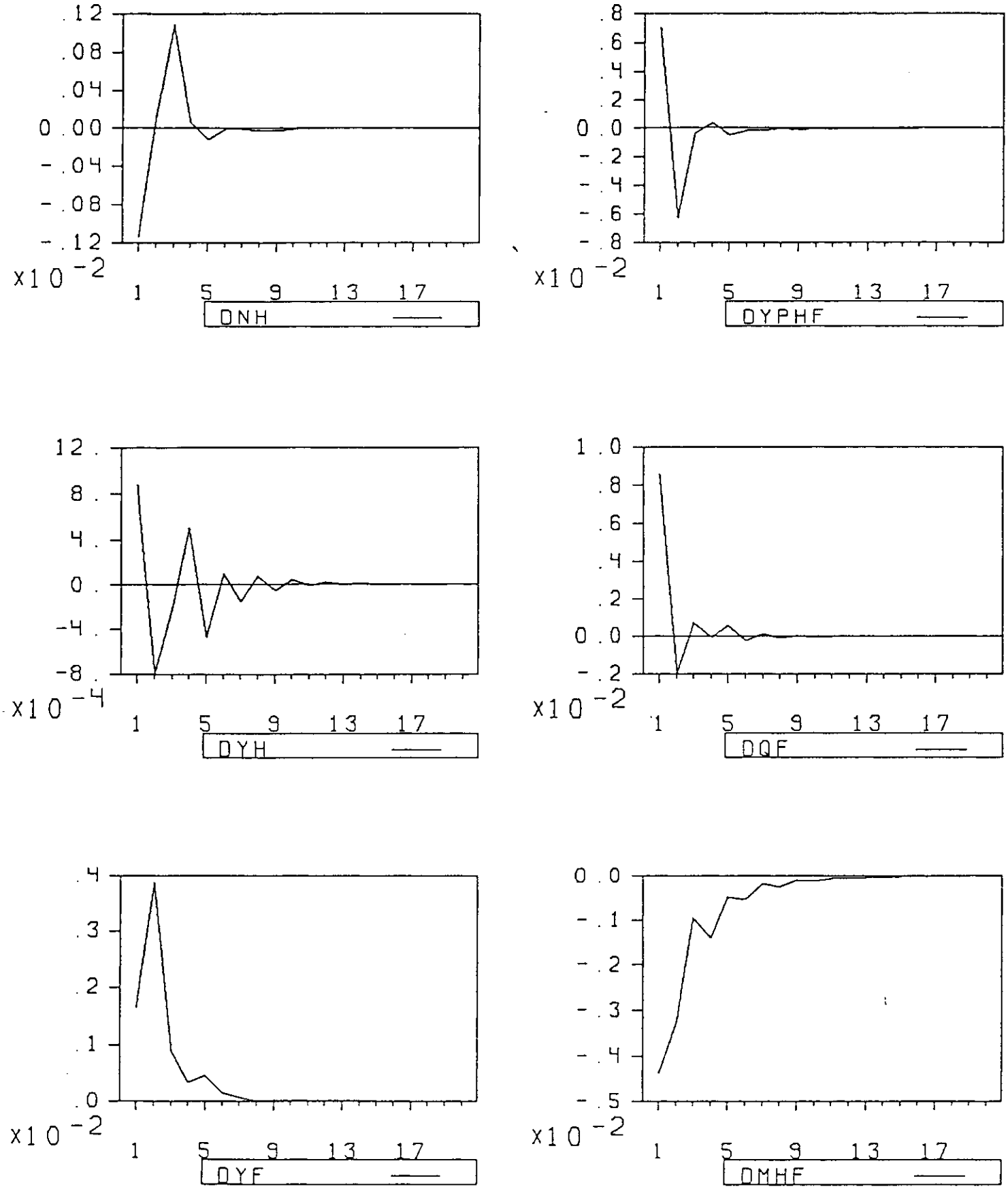
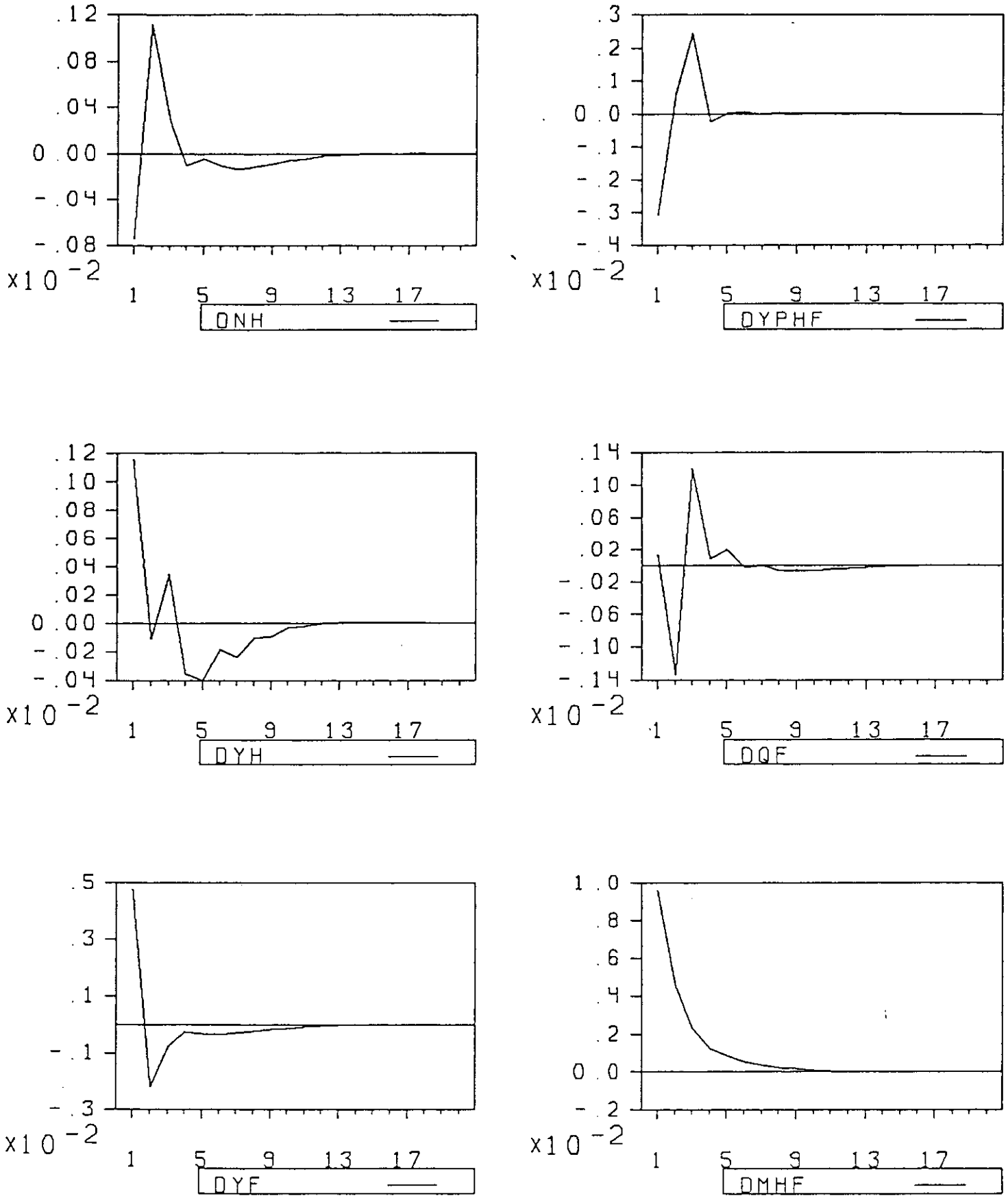


Figure 4: Impulse Responses to SM Shock



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