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Dynamic exchange rate behavior

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by

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For the Graduate College

Iowa State University
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1992

To

My family, especially Charlie

My teachers

And Sheila

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

This study began with an interest in the relation between an exchange rate and prices known as purchasing power parity (PPP). This introduction explains purchasing power parity and cites the basic problem associated with it.

PPP is commonly founded upon the law of one price. Imagine a world free of barriers to trade and transportation costs. In this world, arbitrage equates the domestic price of a good to the foreign price of that good converted into units of domestic currency. For example, suppose the U.S. price of gas is $1/gallon. A U.S. resident may expect to travel across the border to Canada, convert $1 into Canadian dollars (C$), and have sufficient C$ to buy just one gallon of gas. Let p_i (p^*_i) denote the domestic (foreign) currency price of good i. Let S denote the domestic per foreign currency exchange rate. Then the law of one price holds that

$$p_i = Sp_i^*. \tag{1.1}$$

Assuming that the law of one price holds leads one to extend it to an economy-wide proposition. Let PL denote the domestic price level constructed by weighting domestic currency prices. For example, one could let PL = $\Sigma w_i p_i$ where w_i equals the quantity chosen of good i in a consumer's basket. If PL^* denotes the foreign price level constructed according to the same weights used in the domestic price level, the law of one price implies absolute PPP:

$$PL = S \cdot PL^*. \tag{1.2}$$

The presence of trade barriers, transportation costs, etc. break the law of one price and may negate absolute PPP. However one might observe absolute PPP despite failing to observe the law of one price. If the domestic price of good i is above the exchange rate converted foreign price of good i, the domestic price of good j might be below the exchange rate-converted foreign price of good j so that absolute PPP holds. For example, U.S. consumers may pay a higher price for beer while Canadian consumers pay a higher price for hamburgs. In any case, domestic and foreign goods are not apt to substitute well enough to satisfy the absolute PPP hypothesis.

A practical difficulty also rises with absolute PPP. Countries do not publish price levels constructed as above. A researcher may construct price levels or use readily available price indices. Officer (1982) distinguishes between the two approaches by classifying the former as an absolute PPP concept and the latter as a relative PPP concept. Let P and P^* denote domestic and foreign price indices, respectively. Let S_0 denote the exchange rate in some base period. Then the relative PPP proposition is:

$$P = (S/S_0)P^*. \quad (1.3)$$

By choosing the base period exchange rate to correspond to base periods for the price indices, relative PPP will hold by definition in that base period. Relative PPP is weaker than absolute PPP in the sense that it involves comparing price and exchange rate indices as they evolve from a base period. Alternatively, given that parity fails at any point in time, relative PPP predicts that the domestic price index and exchange-rate weighted foreign price index will align over time.

Let me emphasize that absolute PPP entails the use of price levels and relative PPP entails the use of price indices. A researcher may construct price levels where each good's price is equally weighted across countries and study absolute PPP. Or a researcher may use price indices (consumer price index, wholesale price index, or gross product deflator) and study relative PPP. Although I know of no other case where economists distinguish between price "level" and "index," a correct exposition of PPP requires it. Many expositions mistaken equalities like (1.3) as absolute PPP statements or in the interest of brevity begin with alternative relative PPP statements that follow below.

Relative PPP recognizes that parity fails at any point in time. A modification of (1.3) is: $P = k(S/S_0)P^*$, where the constant k accounts for trade barriers, transportation costs, etc. One may expect parity to hold among rates of change:

$$\Delta P = \Delta S + \Delta P^*, \tag{1.4}$$

where ΔP denotes domestic inflation rate; ΔS denotes exchange rate depreciation; ΔP^* denotes foreign inflation rate; and the changes in the constants, k and S_0, equal zero. Dornbusch (1987) claims that relative PPP holds only if economic disturbances are monetary and they satisfy monetary neutrality: an x% change in the quantity of money leads to x% changes in nominal variables and 0% changes in real variables. The implication is that domestic money growth translates into domestic inflation and exchange rate depreciation, so that one may expect (1.4) to hold. Another implication is that (1.4) will not hold in the presence of real economic disturbances.

Another relative PPP statement involves more terminology. The "nominal" exchange rate refers to the domestic currency price of foreign exchange in PPP jargon. Rearranging (1.3) gives:

$$R = (S/S_0)(P^*/P), \qquad (1.5)$$

where R denotes the "real" exchange rate. Relative PPP holds in the base period; the real exchange rate equals one by construction. Values different from one indicate deviations from relative PPP. The real exchange rate represents the relative price of foreign goods in terms of domestic goods and so is sometimes referred to as the terms of trade or "competitiveness."

PPP attracts much empirical interest. Much of the empirical evidence is unfavorable. Despite the abundance of unfavorable empirical evidence, studies continue to be made on account of what Officer calls the "residual validity" of PPP. PPP is generally regarded as an adequate model of exchange rate determination where countries' inflation rates differ widely, that is to say, where prices are the most important determinants of exchange rate behavior. And the performance of PPP is generally regarded as a long run phenomenon.

Exchange rate models incorporate the possibility of successful performance of PPP. At the same time, they explain its demise. This brings us to a basic problem. How does one assess the performance of PPP with an empirical method that we can all agree upon?

Chapter 2 reviews empirical studies of PPP, the role of PPP in a monetary model of exchange rate determination, and time series methods. Chapter 3 presents the Dornbusch (1976) model of exchange rate determination and the Blanchard and Quah (1989) empirical method. Chapter 4 discusses results of the empirical investigation. Chapter 5 concludes the study.

CHAPTER 2

REVIEW OF LITERATURE

As mentioned above, PPP attracts much attention despite the abundance of empirical evidence against it. Isard (1977) studies the law of one price. He showed that percent changes in the exchange rate-weighted relative price of various goods accumulate over time, that is to say, they did not die down in accord with the law of one price. Regression results indicated that exchange rates explained exchange rate-weighted relative prices. Thus the law of one price is a shaky foundation for absolute PPP. Nevertheless the strength of the law of one price versus that of absolute PPP is debatable.

Kravis and Lipsey (1978) gathered data and constructed price levels where the same goods enter each country's price level with equal weights. The weights are U.S. quantities produced in gross domestic product. They showed that absolute PPP failed to hold in 1950 and 1970. Evidently barriers to trade, transportation costs, etc. prevented arbitrage from aligning exchange rate adjusted price levels at these points in time. To the extent that absolute PPP failed at two arbitrary points in time, twenty years apart, some doubt is also cast upon relative PPP.

Take the main implication from these studies to be that domestic-made and foreign-made goods do not adequately substitute across borders so that absolute PPP holds. Relative PPP (just PPP in the sequel) may still hold. Popular models of exchange rate determination incorporate explanations for violations of PPP. The extent of these violations and their causes remains a valid empirical interest.

2.1 Exchange Rate Models

Cassel (1916), credited with naming PPP, put it forth as a theory of exchange rate determination. Most economists regard it inadequate as such. That is to say prices are not the most important determinants of exchange rate behavior. The flow market model determines the price of a currency in a demand and supply setting. The demand for foreign currency arises from the demand for domestic imports. The supply of foreign currency arises from the supply of domestic exports. Most economists regard the flow market model as inadequate too. That is to say trade flows are not the most important determinants of exchange rate behavior.

Modern theory views currency as an asset and the exchange rate as an asset price. The relevant asset market variables (quantities of money, interest rates) become important determinants of exchange rate behavior. Let me put forth one approach with the asset market view that incorporates violations of PPP and illustrates empirical regularities.

The flexible price monetary approach (FPMA) assumes that asset market conditions determine currency prices while goods prices are completely free to adjust. Mussa (1976) is among the original expositors and a good example of them in that he never assumed PPP as is commonly done. Equations characterizing money and foreign exchange markets represent the building blocks of the monetary approach. Consider a discrete-time structural model.

$$m_t = p_t + \bar{y}_t - i_t \tag{2.1.1}$$

$$i_t - i_t^* = E_t e_{t+1} - e_t \tag{2.1.2}$$

$$\bar{y}_t = \delta(e_t + p_t^* - p_t), \quad \delta > 0 \tag{2.1.3}$$

All variables except interest rates are natural log values. Asterisks denote foreign variables. m_t = quantity of money; p_t = price level; $\bar{y}_t$ = full employment real income; i_t = nominal interest rate; $E_t(\cdot)$ = mathematical expectation operator, conditional upon available and relevant information at time t; e_t = domestic per foreign currency exchange rate.

(2.1.1) is money demand where income elasticity and interest semi-elasticity are normalized to one. (2.1.2) is the uncovered interest parity (UIP) relation. UIP assumes that bond traders choose between domestic and foreign bonds solely on the basis of yields, so that arbitrage equates interest rates across borders to the expected rate of exchange rate depreciation.[1] (2.1.3) is aggregate demand where the quantity demanded of aggregate output depends positively on the real exchange rate, that is to say, the relative price of foreign goods in terms of domestic goods. δ indicates the degree of substitution between domestic-made and foreign-made goods. Note that PPP holds as $\delta \rightarrow \infty$. The assumption of price flexibility sets income at the full employment level.

Specifying paths for the exogenous variables closes the model. Assume that each follows a random walk.

$$\begin{aligned} m_t &= m_{t-1} + v_t \\ \bar{y}_t &= \bar{y}_{t-1} + u_t \end{aligned} \tag{2.1.4}$$

Upward trending of the money supply justifies a random walk for the money supply. The likelihood that productivity disturbances have permanent effects justifies a random walk for full employment income. Although some may find these random walk specifications unreasonable, their usefulness lies in the implied reduced forms and the predictions from those reduced forms consistent with empirical regularities.

Assume that the domestic country takes the foreign interest rate and price level as constants; let their values equal zero. Rearranging aggregate demand gives the price level.

$$p_t = e_t - \delta^{-1}\bar{y}_t \tag{2.1.5}$$

Substituting the price level and interest rate into money demand and rearranging gives the exchange rate.

$$e_t = \frac{1}{2}[m_t - (1-\delta^{-1})\bar{y}_t + E_t e_{t+1}] \tag{2.1.6}$$

The above equation implies that the current price of foreign currency depends on current and expected future money supplies and income levels. In order to solve for the expected exchange rate at time t+1, rearrange the above for,

$$E_t e_{t+1} - 2e_t = -z_t, \tag{2.1.7}$$

where $z_t = m_t - (1-\delta^{-1})\bar{y}_t$. Update and take expectations of both sides of the last equation for,

$$E_t e_{t+2} - 2E_t e_{t+1} = -E_t z_{t+1}. \tag{2.1.8}$$

Using the backshift operator, B, let $E_t e_{t+1+i} = B^{-i} E_t e_{t+1}$.[2] Then the last equation becomes a first order difference equation in the one step ahead exchange rate forecast.

$$B^{-1}E_t e_{t+1} - 2B^0 E_t e_{t+1} = -E_t z_{t+1}. \tag{2.1.9}$$

Multiplying both sides by the backshift operator gives,

$$E_t e_{t+1} - 2BE_t e_{t+1} = -BE_t z_{t+1}. \tag{2.1.10}$$

Inverting the polynomial in the backshift operator on the exchange rate forecast leads to,

$$\begin{aligned} E_t e_{t+1} &= \frac{-(2B)^{-1}}{1-(2B)^{-1}}(-BE_t z_{t+1}) \\ &= \frac{1}{2}\sum_{i=0}^{\infty}\left(\frac{1}{2}\right)^i E_t z_{t+1+i} \\ &= \frac{1}{2}\sum_{i=0}^{\infty}\left(\frac{1}{2}\right)^i [m_t-(1-\delta^{-1})\bar{y}_t] \\ &= m_t - (1-\delta^{-1})\bar{y}_t, \end{aligned} \tag{2.1.11}$$

where $E_t z_{t+1+i} = E_t[m_{t+1+i}-(1-\delta^{-1})\bar{y}_{t+1+i}] = m_t-(1-\delta^{-1})\bar{y}_t$, $i \geq 0$. Substituting the exchange rate forecast into (2.1.6) and substituting the random walk specifications for the money supply and full employment income gives the reduced form for the nominal rate:

$$\Delta e_t = v_t - (1-\delta^{-1})u_t. \tag{2.1.12}$$

The reduced forms for price level and real exchange rate easily follow.

$$\Delta p_t = v_t - u_t \qquad (2.1.13)$$

$$\Delta r_t = \delta^{-1} u_t \qquad (2.1.14)$$

Deviations of the real exchange rate from zero indicate deviations from PPP. The income disturbance, a real economic disturbance, is the source of violations of PPP. The better goods substitute across borders, the bigger is δ, and the less severe the violations of PPP.

The reduced forms also exhibit well known empirical regularities of an open economy under floating exchange rates. The reduced form for the nominal rate supports Mussa's (1979) claim that a random walk characterizes nominal rate behavior. The reduced form for the real rate indicates that it too is characterized by a random walk. The presence of income disturbances in each representation explains the comovement observed between nominal and real rates. Units roots in both nominal and real rates indicate the persistence of disturbances, particularly associated with the latter time series.

What empirical regularities do the reduced forms not exhibit? Macdonald (1988) tabulates standard deviations of percent changes in nominal rates that generally exceed those for money supplies and price levels over the current period of floating. Although the reduced form for the change in the nominal rate implies that its variance exceeds that of the change in the money supply, it fails to explain the greater variance in exchange rates than price levels.

To the extent that some economists regard short run exchange rate responses to economic disturbances as greater than long run responses, the reduced forms provide no explanation. The lack of an explanation lies in the flexible price assumption of this particular monetary approach. If prices are slow to adjust, or "sticky," then short run exchange rate responses may exceed long run responses. Such behavior is called "overshooting." Its presence is not well established as an empirical regularity. The sticky price monetary approach (SPMA) nests the FPMA as a special case. It accounts for the overshooting phenomenon and thus sets the stage for incorporating more things to look for in the empirical study.

Frankel (1979) compared FPMA and SPMA models. He advocated his own "real interest differential" model which nested the former two. Later, motivated to explain a dollar depreciation over 1977 to 1978 not well explained by the monetary approach, Frankel (1983) set out to compare the monetary approach to an alternative asset market view: the portfolio balance approach. Whereas the monetary approach relies on perfect capital substitutability, the portfolio balance approach stresses imperfect capital substitutability: bond traders consider bond yields, exchange rate depreciation, and currency risk. Results lead him (p. 105) "...tentatively to justify a return of attention to the monetary approach." So I turn to a more general presentation of the SPMA model in Chapter 3.

2.2 Time Series Methods

The aforementioned study by Kravis and Lipsey showed that PPP fails at arbitrary points in time. Point in time comparisons ignore all that happens in the interim. Subsequent research sought to detect the persistence of violations of PPP, namely, disturbances to the real exchange rate. Thus time series methods become useful. If a real exchange rate time series is stationary, then by definition the disturbances to it die down to zero over time. On the other hand if the real exchange rate follows a random walk, then by definition disturbances have permanent effects. Enders (1988) applied a stationarity test to real exchange rates and failed to reject the null hypothesis of a random walk for real rates. Specifically, he concluded that PPP fails to perform well as a long run phenomenon.

Given that disturbances to the real exchange rate are permanent, is there anything left to say about PPP? Yes there is. Even though the effects of a disturbance to the real rate may be permanent, its effects may attenuate over time. More formally, the real rate may contain a unit root where its first differences are negatively serially correlated. In this weak sense, PPP characterizes long run real exchange rate behavior.

Huizinga (1987) proceeded along this line. He sought to detect mean reversion in real rates by applying a spectral procedure due to Cochrane (1988) and a regression procedure due to Fama and French (1988). First consider Huizinga's application of the spectral procedure. Let r_t denote the real exchange rate and Δr_t its covariance stationary first difference. Let $S_{\Delta r}(0)$ denote 2π times the spectral density of the first difference of the real rate evaluated at frequency zero:

$$S_{\Delta r}(0) = \gamma_0 + 2\sum_{i=0}^{\infty} \gamma_i, \tag{2.2.1}$$

where $\gamma_i = C\{\Delta r_t, \Delta r_{t-i}\}$, the covariance between the first difference of the real rate and its i^{th} lag. Dividing $S_{\Delta r}(0)$ by the variance of the change in the real rate gives a statistic indicative of the time series characterization of the real rate:

$$s_{\Delta r}(0) = \frac{S_{\Delta r}(0)}{\gamma_0} = 1 + 2\sum_{i=0}^{\infty} \rho_i, \qquad (2.2.2)$$

where $\rho_i = C\{\Delta r_t, \Delta r_{t-i}\}/V\{\Delta r_t\}$, the autocorrelation between the change in the real rate and its i^{th} lag. If the real rate is a random walk then its changes exhibit no autocorrelation and $s_{\Delta r}(0) = 1$. If the real rate reverts to its mean due to negative autocorrelation in its changes then $0 < s_{\Delta r}(0) < 1$. If the real rate is stationary then $s_{\Delta r}(0) = 0$. If the effects of disturbances to the real rate are enhanced over time then $s_{\Delta r}(0) > 1$.

In order to illustrate the usefulness of $s_{\Delta r}(0)$ as an indicator of the time series model characterizing the real rate, Huizinga appeals to the decomposition of the real rate into permanent and transitory components. Disturbances to the permanent component of a time series have permanent effects. Disturbances to the transitory component have temporary effects. Let the decomposition be:

$$r_t = r_{pt} + r_{\tau t}, \qquad (2.2.3)$$

where r_{pt} and $r_{\tau t}$ are respectively, permanent and transitory components. Huizinga follows Beveridge and Nelson (1981) by representing the permanent component as a random walk. However, Quah (1989, p.4) claims: "There is no reason to restrict [the permanent component] a priori to be a random walk as is usually done in the literature."

Using Quah's Proposition 3.1,

$$s_{\Delta r}(0) \leq \frac{(q+1)\,V(\Delta r_{pt})}{\gamma_0}, \tag{2.2.4}$$

where q denotes the order of moving average representation for the change in the permanent component, Δr_{pt}. Huizinga considered only a random walk permanent component (q = 0). In that case the ratio of variance of change in the permanent component to variance of change in the real rate is a lower bound on $s_{\Delta r}(0)$. An estimate of $s_{\Delta r}(0)$ below one indicates mean reversion and a transitory component. However an estimate of $s_{\Delta r}(0)$ below one does not indicate a random walk permanent component. The main point is that although spectral results may uncover an important transitory component and justify assuming a random walk permanent component, they do not rule out infinitely many other permanent-transitory decompositions. More on this below with respect to real rate overshooting.

Although a theoretical decomposition of the real rate into permanent and transitory components motivates the spectral procedure, one need not decompose the real rate into permanent and transitory components to carry it out. Huizinga estimates $s_{\Delta r}(0)$ according to:

$$\hat{s}_{\Delta r}(0) = 1 + 2\sum_{i=0}^{N} w_i^N \hat{\rho}_i, \qquad (2.2.5)$$

where N denotes the number of estimated autocorrelations ($\hat{\rho}_i$) used and w_i^N weights low order autocorrelations greater than high order autocorrelations. Plots of $\hat{s}_{\Delta r}(0)$ versus N generally show a humped shaped pattern where $\hat{s}_{\Delta r}(0)$ rises above one and falls to 0.58 on average in ten cases. This evidence supports mean reversion in the real exchange rate, i.e., negative autocorrelation in the first difference.

Without imposing any moving average order on the change in the permanent component, Huizinga's results show that the relative importance of a permanent component to real rate movements is small enough to indicate an important transitory component. In other words, spectral results are consistent with choosing a random walk permanent component but, due to Quah's results, do not rule out the possibility of a moving average process for the change in the permanent component.

All else is not well for these results from the spectral procedure. Huizinga estimates $s_{\Delta r}(0)$ with a maximum of 132 autocorrelations based on monthly data for the current floating exchange rate period, in effect approximating infinity with the number 132. Although the estimates appear to converge, one may object to characterizing "long run" behavior as short as say, a year, with less than twenty "long runs" over the less than twenty years of current exchange rate floating.

Fama and French (1988) sought to detect mean reversion in stock prices. Their strategy is the regression procedure. It entails regressing k-period ahead changes in a time series on k-period lags. The regression coefficient is the k^{th} order autocorrelation of the change in the real rate over k periods, or

$$\beta_k = \frac{C\{r_{t+k}-r_t, r_t-r_{t-k}\}}{V\{r_t-r_{t-k}\}}. \quad (2.2.6)$$

Negative values for β_k indicate mean reversion. According to Huizinga: β_k is bounded by -1 and 1 for finite k; equals zero in the limit for a random walk; approaches zero in the limit for a difference stationary process; and equals -1/2 in the limit for a covariance stationary process. The validity of the regression procedure remains intact. Huizinga reports negative estimates of β_k, consistent with a mean reverting real rate and the long run success of PPP, but the estimates are not significantly different from zero. However with Huizinga's maximum long run of four years and less than twenty years of exchange rate floating, he has less than five observations on the long run. That hardly seems like enough data to characterize long run behavior.

Huizinga also investigates the overshooting phenomenon by comparing a random walk permanent component of the real rate to the actual real rate. Problems arise here. First, although Huizinga finds evidence of real rate overshooting, this depends on his obtaining the random walk permanent component from fitting high order autoregressive models to the first difference of the real rate. He admits (p. 196): "If one has strong a priori information that real exchange rates follow a low-order autoregression, use of this information is sufficient to rule out evidence of exchange-rate overshooting." The version of the Dornbusch model in the next chapter implies a reduced form for the real rate that follows such a low order autoregression. Second, Quah's point that permanent components need not be assumed to follow random walks becomes relevant. Huizinga's spectral results consistent with a random walk permanent component in the real rate justify his assuming a random walk permanent component to investigate overshooting. But according to Quah's results, other researchers are free to choose among other permanent-transitory decompositions which would likely lead to different results on the overshooting phenomenon.

Buiter's (1987) comment on Huizinga's paper raises a third issue with respect to drawing conclusions on overshooting from a univariate analysis. He explains (p. 217):

> The overshooting hypothesis is about the effect of some exogenous variable (...typically the level or growth rate of the nominal money stock...) on some endogenous variable (... typically the level of the nominal or real exchange rate). It therefore takes at least a bivariate analysis (e.g., a time series characterization of the money stock and the (real) exchange rate processes) to say anything about the overshooting hypothesis.

Buiter put forth a version of the Dornbusch model as the appropriate foundation for an empirical investigation of the overshooting phenomenon. The time series model due to Blanchard and Quah (1989) is the choice method for relating movements in macroeconomic variables to disturbances in the open economy. Lee and Enders (1991) interpret nominal and real exchange rate responses due to shocks having temporary and permanent effects in the context of the Dornbusch model. I extend the work of Lee and Enders.

CHAPTER 3

MODEL AND METHOD

3.1 Model

As the present study progressed, it became evident that the Dornbusch (or SPMA) model was appropriate to study PPP, the degree of price flexibility, and exchange rate overshooting. The Dornbusch model of a small open economy illustrates the presence of temporary and permanent disturbances to exchange rates, price, and output. The economy is small in the sense that it takes the foreign interest rate and price level as given. In practice this means we view the U.S. as the foreign country and the other country as the domestic country. Consider the following stripped down, discrete-time version of the model close to that presented in Buiter.

$$m_t - p_t = ky_t - \lambda i_t \quad k,\lambda>0 \qquad (3.1.1)$$

$$i_t - i_t^* = E_t e_{t+1} - e_t \qquad (3.1.2)$$

$$y_t = \delta(e_t+p_t^*-p_t) - \sigma i_t + x_t \quad \delta,\sigma>0 \qquad (3.1.3)$$

$$p_{t+1}-p_t = \phi(y_t-\overline{y}_t) \quad \phi>0 \qquad (3.1.4)$$

All variables except interest rates are in natural logs. Variables superscripted with asterisks denote foreign magnitudes. The ways in which the model is stripped down will be discussed below.

(3.1.1) is the demand for money where the quantity of money demanded (m_t) is equiproportional to the price level (p_t), varies positively with real income (y_t), and negatively with the nominal interest rate (i_t). The income and interest elasticities of money demand are k and λ, respectively. Although there is no monetary disturbance added to the right hand side of (3.1.1), a monetary disturbance will arise from the money supply and real disturbances will arise from aggregate demand and full employment income.

(3.1.2) is the uncovered interest parity (UIP) relation. The difference between the domestic interest rate and the foreign interest rate (i_t^*) equals the expected appreciation (or depreciation) of the nominal exchange rate (e_t). The nominal rate is defined as the domestic currency price of foreign currency so that an increase in e_t denotes a depreciation of the domestic currency. $E_t(\cdot)$ is the mathematical expectation operator, conditional on available and relevant information at time t. Agents form their expectations rationally. UIP holds that agents trade domestic and foreign bonds solely on the basis of yield and expected exchange rate changes. Mussa (1979) lends support to UIP as a long run phenomenon. Recently, Froot and Thaler (1990) document the lack of empirical evidence in support of UIP and claim that a risk premium or expectational error term is missing on the right hand side.

(3.1.3) is aggregate demand. The real exchange rate is denoted by $e_t+p_t^*-p_t$. x_t denotes a demand shift parameter representing changes in government spending or foreign income. The aggregate demand equation is simplified by eliminating the consumption spending component. δ indicates the degree of substitutability between domestic and foreign made goods. The higher the value of δ, the better the goods serve as substitutes. As δ tends to infinity, the real exchange rate approaches zero and PPP prevails. σ represents the sensitivity of spending by firms to changes in the interest rate.

Prices are sticky in this model. The current price level is predetermined or in other words, aggregate supply is infinitely elastic. (3.1.4) defines the inflation rate where the price level rises between times t and t+1 when output rises above the full employment level ($\bar{y}_t$). Dornbusch describes the inflation rule as a combination of Okun's law and the Phillips curve. According to Okun's law, a 1 percentage point drop in the unemployment rate leads to a 2 or

3 percentage point increase in income. The Phillips curve posits a short run tradeoff between inflation and unemployment. Thus the price level rises whenever income is above the full employment level in the short run. In the long run, income is at the full employment level and the price level is constant.

The sticky price assumption implies that exchange rates respond to economic disturbances on impact while the price level does not. The conventional justification for sluggish price adjustment is nominal wage rate rigidities. Okun (1981) claims that producers resist immediate price changes in order to maintain goodwill. McCallum (1986) argues that the benefits of indexation, which would increase price flexibility, simply fall short of the costs. In any case, many economists regard the sticky price assumption as realistic and it is necessary (but not sufficient) to predict overshooting.

As mentioned above, the model is stripped down in the sense that the consumption component of aggregate demand is excluded. Let me strip it down further by normalizing various other money demand and aggregate demand elasticities: $k = \lambda = \sigma = 1$. These common simplifying assumptions ease the derivation of reduced forms. Although they entail some cost, e.g., explicitly seeing the role of interest elasticity of the demand for money in exchange rate responses, the assumptions do not prevent identifying permanent versus temporary movements in exchange rates and output. Take the model for its illustrative value.

In order to solve the model, normalize the foreign interest rate and natural log of the foreign price level to zero. Assume that the exogenous processes of the money supply, demand shift parameter, and full employment income follow random walks.

$$\begin{aligned} m_t &= m_{t-1} + v_t \\ x_t &= x_{t-1} + w_t \\ \bar{y}_t &= \bar{y}_{t-1} + u_t \end{aligned} \tag{3.1.5}$$

Assuming random walks for the exogenous processes makes disturbances to them persistent. For example, Buiter shows that if the money supply were a stationary first order autoregressive process, monetary disturbances would have temporary effects. Stockman (1987) argues that real disturbances are important sources of persistent deviations in the real exchange rate. Random walk characterizations of the demand shift parameter and full employment income generate that result. We will see whether the permanent disturbances to the exogenous processes lead to permanent or temporary movements in the endogenous variables, namely the nominal exchange rate, real exchange rate, and output. See Appendix A for the model solution and reduced forms.

Reduced forms all contain unit roots indicating nonstationarity in exchange rates, price, and output and persistent disturbances. Where polynomials in the lag operator exist on the monetary and real disturbances, permanent disturbances will die down or be enhanced over time. Such behavior is the implication of sluggish price adjustment. Otherwise with completely flexible prices, the endogenous variables exhibit constant responses at all future horizons due to disturbances in the exogenous variables.

How does the model work? The asset market always equilibrates. The goods market fails to equilibrate at all times due to sticky prices, in which case the exchange rate aids adjustment. Suppose the money supply increases. The domestic per foreign currency exchange rate increases, i.e., the domestic currency depreciates, while the price level initially remains constant. Although the asset market equilibrates, a shortage exists in the goods market. Without a higher price level, the domestic currency aids adjustment by "overshooting" its long run depreciation determined by the size of the increase in the money supply.

Dornbusch describes the domestic currency depreciation as large enough so as to induce an expected appreciation. The expected appreciation leads investors to buy domestic bonds and hence appreciate the domestic currency. Meanwhile the domestic price level increases and goods market equilibrium follows. In sum, an x% increase in the money supply eventually leads to equiproportionate increases in the nominal exchange rate and price level, with no change in the real exchange rate. In other terminology, an increase in the quantity of money only temporarily raises "competitiveness" (the real exchange rate) and output.

If output is permitted to deviate from the full employment level, as in the present setup, there is the possibility that the nominal rate will undershoot its long run depreciation due to a monetary disturbance. If the price level is sticky, a monetary disturbance will increase output in the short run. The increase in income raises the demand for money and hence the interest rate. Undershooting occurs when the decrease in the interest rate due to the increase in the money supply is more than offset by the increase in money demand due to the increase in income. Bond traders need not expect an appreciation of the domestic currency to induce them to buy up domestic bonds. Instead, domestic and foreign bond yields are equalized by the positive income effect of money demand on the interest rate. In general, a high income elasticity of money demand coupled with a high degree of substitutability between domestic and foreign output creates the possibility of undershooting.

Recall the derivation of reduced forms in Appendix A. Reduced forms show contemporaneous responses and the adjustment path to long run responses in terms of the structural model parameters. Adjustment takes the form of overshooting, undershooting, or one time jumps. Consider the nominal exchange rate responses to positive monetary, demand, and income disturbances.

$$\frac{\partial e_t}{\partial v_t} = \frac{2(1-\rho_1)+1}{2(1-\rho_1)+\delta} \gtrless \frac{\partial e_{t+s}}{\partial v_t} = 1 \ as\ s \to \infty$$

$$\frac{\partial e_t}{\partial w_t} = \frac{-1}{\delta} = \frac{\partial e_{t+s}}{\partial w_t} = as\ s \to \infty$$

$$\frac{\partial e_t}{\partial u_t} = \frac{2(1-\rho_1)\frac{1-\delta}{\delta}}{2(1-\rho_1)+\delta} \gtrless \frac{\partial e_{t+s}}{\partial u_t} = \frac{1-\delta}{\delta} \ as\ s \to \infty$$

The nominal rate will contemporaneously increase due to a positive monetary disturbance. That is to say, the domestic currency depreciates. The long run response is an equiproportionate depreciation. Whether overshooting or undershooting occurs is ambiguous. The reason being that with a predetermined price level, an increase in the money supply will influence output. In general, the short run depreciation may fall short of the long run depreciation if the increase in income leads to sufficiently large increases in money demand and hence the interest rate. On the other hand, the less well domestic and foreign goods serve as substitutes (smaller δ), or the less flexible the price level (small ϕ), the greater is the likelihood of overshooting. Positive demand disturbances appreciate the domestic currency at impact and by the same amount thereafter. The nominal rate overshoots or undershoots the long response due to an income disturbance depending on the size of δ. Note in passing that all disturbances have permanent effects on the nominal rate.

Consider real exchange rate responses which exhibit divergences from PPP and long run monetary neutrality.

$$\frac{\partial r_t}{\partial v_t} = \frac{1+2(1-\rho_1)}{2(1-\rho_1)+\delta} > \frac{\partial r_{t+s}}{\partial v_t} = 0 \; as \; s \rightarrow \infty$$

$$\frac{\partial r_t}{\partial w_t} = \frac{-1}{\delta} = \frac{\partial r_{t+s}}{\partial w_t} = as \; s \rightarrow \infty$$

$$\frac{\partial r_t}{\partial u_t} = \frac{2(1-\rho_1)\frac{1-\delta}{\delta}}{2(1-\rho_1)+\delta} < \frac{\partial r_{t+s}}{\partial u_t} = \frac{1}{\delta} \; as \; s \rightarrow \infty$$

The fact that all contemporaneous real rate responses match the corresponding nominal rate responses reflects sticky prices. The real value of the domestic currency falls, due to a positive monetary disturbance, but the effect is temporary. In this sense, the monetary authority cannot make the economy more competitive. And the temporary nature of monetary disturbances means that if all disturbances were monetary, PPP would hold in the long run. Positive demand disturbances cause the real rate to immediately appreciate and remain there for the long run. A positive income disturbance, or productivity disturbance if you will, permanently increases competitiveness. Note in passing that a negative demand disturbance, perhaps arising from a negative disturbance to foreign productivity, also permanently raises competitiveness.

Output responses exhibit long run monetary neutrality and some properties of a flexible exchange rate regime.

$$\frac{\partial y_t}{\partial v_t} = \frac{1-\rho_1+\delta+(1-\rho_1)\delta}{2(1-\rho_1)+\delta} > \frac{\partial y_{t+s}}{\partial v_t} = 0 \text{ as } s \rightarrow \infty$$

$$\frac{\partial y_{t+s}}{\partial w_t} = 0 \text{ for all } s$$

$$\frac{\partial y_t}{\partial u_t} = \frac{(1-\rho_1)(1-\delta)}{2(1-\rho_1)+\delta} \gtrless \frac{\partial y_{t+s}}{\partial u_t} = 1 \text{ as } s \rightarrow \infty$$

Monetary policy is effective: an increase in the money supply will temporarily raise the level of output. Fiscal policy is ineffective. In fact the demand disturbance, which may represent government spending, does not appear in the reduced form for output. An increase in government spending is completely offset by a decrease in the real exchange rate and increase in imports, leaving no net change in aggregate demand. (Incidentally, demand disturbances do not influence the price level for the same reason.) Naturally, income disturbances are the only source of permanent changes in income, affecting income equiproportionally in the long run.

Given that the empirical method put forth below does not use data on money and aggregate demand components to generate disturbances, nor does it distinguish between domestic and foreign disturbances, the theoretical impulse responses will help interpret estimated impulse responses. The empirical investigation will focus on establishing regularities in exchange rate and output behavior and assessing the relative importance of each disturbance. The theoretical long run responses will also be used to justify a restriction on the long run behavior of the real exchange rate and output in order to identify a time series model.

3.2 Method

After studying the theoretical model and its reduced forms, the empirical strategy may take a reduced form or structural model approach. This study adopts the former. The benefit of a reduced form approach is that it allows the endogenous variables to behave under minimum restrictions, which is a good thing in case the theoretical model is misspecified. Misspecification may be due to a violation of UIP. Meese and Rogoff (1983) suggest that the poor out of sample forecasts of exchange rate models with the monetary approach is due to instability of money demand. The cost involves side-stepping a line by line evaluation of the structural model and failing to see which aspects might not perform suitably. Actually, some structure implied by the theoretical model will be imposed on the empirical model. That structure is the long run behavior of the real exchange rate and output.

The empirical method is due to Blanchard and Quah. Cast two stationary time series, say the first differences of the nominal and real exchange rates, into the vector X_t = $[\Delta e_t, \Delta r_t]'$.[3] Then the following infinite order vector moving average (VMA) or Wold representation exists.

$$\begin{aligned} X_t &= C(L)\eta_t, \; var(\eta_t) = I \\ &= C(0)\eta_t + C(1)\eta_{t-1} + \cdots \end{aligned} \qquad (3.2.1)$$

Impulse response functions trace exchange rate movements affected by the shocks in η_t. Variance decompositions detect the relative importance of shocks. Both interpretive techniques follow from representation (3.2.1) which I will refer to as the "working model." Blanchard and Quah explain how to decompose, in this case, exchange rates, into permanent and transitory components.

The goal is to identify the working model. Let the elements of the shock vector be denoted as $\eta_t = [\eta_{nt}, \eta_{rt}]'$. Following Lee and Enders, refer to the top and bottom elements of η_t as "nominal" and "real" shocks, respectively. Recall the Dornbusch model prediction that monetary disturbances temporarily affect the level of the real exchange rate. The identification scheme forces the nominal shock to capture the temporary effects of a monetary disturbance on the level of the real rate. This strategy implies the following "long run restriction:" $C_{21}(L=1) = 0$.[4] Note in passing that the identification scheme leaves real shocks to capture the effects of demand or income disturbances.

The long run restriction is one of four needed to identify the working model. It and the three others come into play as follows. Assume the existence of the following finite order vector autoregressive representation (VAR):[5]

$$\begin{aligned} X_t &= A(L)X_{t-1} + \epsilon_t, \ var(\epsilon_t) = \Omega \\ &= A(1)X_{t-1} + \cdots + A(p)X_{t-p} + \epsilon_t. \end{aligned} \tag{3.2.2}$$

Since X_t is stationary, the VAR inverts to the infinite order VMA:

$$\begin{aligned} X_t &= B(L)\epsilon_t \\ &= \epsilon_t + B(1)\epsilon_{t-1} + \cdots, \end{aligned} \tag{3.2.3}$$

where $B(L) = [I-A(L)L]^{-1}$. Transforming the VMA gives the working model.

Matching first terms on right hand sides of the working model and the VMA gives $C(0)\eta_t = \epsilon_t$. Matching s^{th} terms gives $C(s)\eta_{t-s} = B(s)\epsilon_{t-s}$, which after substituting for $\epsilon_{t-s} = C(0)\eta_{t-s}$ gives $C(s) = B(s)C(0)$. Summing each side of the last equality from zero to infinity gives $C(L=1) = B(L=1)C(0)$, or

$$\begin{bmatrix} C_{11}(L=1) & C_{12}(L=1) \\ C_{21}(L=1) & C_{22}(L=1) \end{bmatrix} = \begin{bmatrix} B_{11}(L=1) & B_{12}(L=1) \\ B_{21}(L=1) & B_{22}(L=1) \end{bmatrix} \begin{bmatrix} c_{11}(0) & c_{12}(0) \\ c_{21}(0) & c_{22}(0) \end{bmatrix}. \quad (3.2.4)$$

The above expression gives the contemporaneous effects of nominal and real shocks in C(0) and the long run effects in C(L=1). The following restriction forces the nominal shock to temporarily affect the level of the real exchange rate and puts one restriction on C(0): $C_{21}(L=1) = B_{21}(L=1)c_{11}(0) + B_{22}(L=1)c_{21}(0) = 0$. Taking the variance of each side of $C(0)\eta_t = \epsilon_t$ gives the following "variance restrictions:" $C(0)C(0)' = \Omega$, or

$$\begin{aligned} c_{11}(0)^2 + c_{12}(0)^2 &= \omega_{11} \\ c_{11}(0)c_{21}(0) + c_{12}(0)c_{22}(0) &= \omega_{12} \\ c_{21}(0)^2 + c_{22}(0)^2 &= \omega_{22}. \end{aligned} \quad (3.2.5)$$

The long run and variance restrictions combine for a total of four restrictions, sufficient to just identify C(0) and the working model. The remaining C(s), s≥1, follow from C(s) = B(s)C(0).[6] See Appendix B for a summary of the identification procedure.

Let me put Blanchard and Quah's discussion of the limitations of the identification scheme into the context of this study of exchange rates and output. The authors first point out that assuming the nominal and real shocks to be uncorrelated is not a limitation at all since it does not affect the ways in which the shocks influence endogenous variables. Second, they entertain the argument that nominal shocks might have permanent effects. This possibility is remote when we liken the nominal shock to a monetary disturbance and restrict real exchange rate behavior. However the nominal shock can be likened to a demand disturbance with temporary effects on the level of output. It is for that case that Blanchard and Quah admit the possibility of permanent effects stemming from nominal shocks. Yet they argue that any permanent effects of a nominal shock are apt to be small, relative to those of real shocks. And they prove that if the permanent effects of a nominal shock are arbitrarily small, compared to those of a real shock, then the decomposition is "nearly correct."

The third limitation recognizes the presence of more than one of each type of shock. For example, the above version of the Dornbusch model recognizes two real types: demand and income disturbances. Blanchard and Quah prove that the identification scheme is correct provided that the nominal and real exchange rates exhibit "sufficiently similar" responses across multiple nominal and real shocks. By sufficiently similar they mean that the distributed lag polynomials may differ by no more than a scalar lag distribution. The implication is to compare the responses of the two variables for some degree of similarity across multiple shocks of the same type. If for example, nominal and real exchange rate responses to two real shocks appear to differ substantially, then the bivariate results are misleading. See Appendix B for a discussion of the necessary and sufficient conditions for bivariate results to not be misleading.

Despite the possibility of obtaining meaningful bivariate results in light of recognizing the three a priori disturbances, the identification of a trivariate version of the working model could resolve this issue.

3.3 A Trivariate Model

The strategy is similar to that for the bivariate model. Add the first difference of output to the vector $X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$. Let the shock vector be: $\eta_t = [\eta_{nt}, \eta_{r1t}, \eta_{r2t}]'$, where the first element is a nominal shock intended to capture the effects of a monetary disturbance, the second is a real shock intended to capture the effects of a demand disturbance, and the third is a real shock intended to capture the effects of an income disturbance. In particular, the nominal shock is restricted to have temporary effects on the levels of the real exchange rate and output and the first real shock is restricted to have a temporary effect on the level of output.

The long run restrictions give three equations in the nine unknown elements of C(0). The variance restrictions provide the remaining six equations for a total of nine to just identify C(0). A problem surfaces due to the nonlinear variance restrictions: the nine equations cannot be solved by hand. Thus C(0) is assumed to be upper triangular and the working model will be overidentified. The assumption facilitates the empirical method. Moreover its reasonableness can be tested as a statistical hypothesis in the estimation of a restricted VAR. See Appendix C for the identifying equations and the restrictions overidentification imposes on VAR estimation.

CHAPTER 4

RESULTS

4.1 Data

The demise of the Bretton Woods System of fixed exchange rates occurred in 1971. The Smithsonian Agreement to re-establish fixed rates collapsed by March, 1973. One may take January, 1973 to the present as the current period of floating exchange rates. Exchange rate, wholesale price, and industrial production data for the U.S., Japan, Germany, Canada, France, Italy, and the U.K. (G-7 countries) come from various issues of International Financial Statistics (IFS). Wholesale price data for Argentina and Brazil come from IFS; exchange rate data come from Pick's Currency Yearbook and the World Currency Yearbook. All data were indexed so that the January, 1973 (1973:1) observation is 1. Natural log values were used for analysis. For example, all nominal and real exchange rates equal zero for 1973:1 and deviate from there afterward. See Figures 1.1-1.8 for the nominal and real rate time series.

4.2 Comments on PPP

Trends and smooth behavior of nominal and real rates over time indicate nonstationarity. Viewing nominal and real rates acquaints one with the basics and empirical regularities of

PPP. Take the yen per dollar rates in Figure 1.1 which are characteristic of the G-7. The nominal rate is the nominal value of the dollar in terms of yen. The real rate approximates the real value of U.S. goods and services in terms of Japanese goods and services. The higher the real rate, the more Japanese-made goods a U.S. citizen can obtain for a U.S.-made good, and hence the more competitive the Japanese economy. Given that the real yen value of the dollar appears to differ from a white noise time series, one may reasonably argue that PPP fails. That is to say, changes in the nominal yen value of the dollar fail to be accompanied by offsetting changes in wholesale prices. Another way to see the apparent failure of PPP in the Japanese data is to notice that changes in the nominal yen value of the dollar accompany changes in the real yen value of the dollar in the same direction. For example, the U.S., Japan, Germany, France, and the U.K. met in the fall of 1985 and agreed to lower the nominal value of the dollar. Notice that the effort lowered both nominal and real values of the dollar, making the U.S. economy more competitive, in contrast to the prediction of PPP.

According to Mussa (1979), one may detect PPP as a long run empirical regularity in highly inflationary economies. Argentinean and Brazilian exchange rates in Figures 1.7 and 1.8 show PPP at work. Hyperinflation in both economies translates into nominal depreciations of the peso and cruzeiro. However real rates remain constant relative to nominal rates. Leaving actual governmental intentions aside, lowering dollar prices of pesos and cruzeiros fails to lower the relative prices of Argentinean and Brazilian goods and services in terms of U.S. goods and services. And as the Dornbusch model predicts, PPP holds in a world where disturbances are primarily monetary.

4.3 Bivariate Results

A discussion of results from modeling nominal and real exchange rates ($X_t = [\Delta e_t, \Delta r_t]'$) according to the discussion in 3.2 follows. Recall that the first step in the empirical procedure is to estimate a VAR. Given that each equation in a VAR has the same explanatory variables, there is no possible gain in efficiency by estimating the system as a seemingly unrelated regression (SUR) model. The software package chosen for all statistical analysis is Regression Analysis of Time Series (RATS). RATS estimates a VAR using ordinary least squares (OLS) equation by equation and outputs the residual covariance matrix.

The selection of lag length for a VAR poses a problem in that different lag lengths might lead to different results. For example, the speed of adjustment in dependent variables due to shocks will be faster in low order models than high order models. A statistical test to select lag length is appropriate. Here I employ the likelihood ratio suggested by Sims (1980).[7]

Table 1 gives VAR lag length test results. Lee and Enders estimated sixth order VARs. Here we see that less than six lags are sufficient. Note in passing that a low order VAR is consistent with the reduced forms for nominal and real rates obtained from the Dornbusch model.[8]

Impulse response functions show the dependent variable adjustment to a shock of one standard deviation, transformed to unity, in size. Begin with nominal rate impulse response functions in Figures 2.1A-2.8A. All nominal rates initially increase in response to a positive nominal shock, which is to say that all domestic currencies depreciate as though the nominal shock were a domestic monetary disturbance. The sign of the response is difficult to interpret, however, given that the empirical method does not distinguish between domestic and foreign shocks. We have no way of knowing from where a shock emanates. One might be suspicious if the peso and cruzeiro nominal rate responses to positive nominal shocks were not depreciations, given the excessive money growth in those economies, but Figures 2.7A and 2.8A show this not to be the case.

Now focus on the paths followed from impact to the long run response. The mark, franc, lira, peso, and cruzeiro per dollar rates exhibit undershooting. Only the Canadian dollar rate overshoots. The yen and pound per dollar rates jump once and for all, when the nominal shock impacts, to the long run responses. The presence of overshooting indicates sticky prices. The lack of overshooting suggests price flexibility. Recall that the Dornbusch model also explains undershooting as the result of a high income elasticity of money demand together with a high degree of substitutability between goods across borders. Domestic monetary disturbances that raise income also increase money demand and perhaps the interest rate. In that case bond traders need not expect an appreciation of the domestic currency to buy back domestic bonds; they are compensated with a higher domestic bond yield.

Imperfect capital mobility may explain undershooting in Argentinean and Brazilian data. Frenkel and Rodriguez (1982) relax the assumption of perfect capital mobility (UIP) and write net capital inflows proportional to: the domestic-foreign interest rate differential minus expected exchange rate depreciation. A monetary expansion lowers the interest rate, depreciates the domestic currency, creates a trade balance surplus, and creates a capital account deficit. If capital mobility is low, agents anticipate more depreciation of the domestic currency. The immediate response of the nominal exchange rate is less than the long run response. Over the long run, the price level increases, the interest rate rises, and trade and capital flows balance.

Nominal rate responses to the real shock help determine whether the bivariate model captures the effect of a demand or income disturbance. The one time jumps to long responses, exhibited by the yen, mark, and pound rates, pattern the predicted response to a negative demand disturbance. Responses different at impact than in the long run suggest the effects of an income disturbance. The fast speed of adjustment observed in the yen, mark, and Canadian dollar rates indicates greater price flexibility than in the other economies where the franc, lira, peso, and cruzeiro rates take over twelve months to adjust.

Taken together, nominal rate responses have no common characteristics. If not for the nominal franc rate response to a real shock and the nominal pound response to a nominal shock, both shocks would leave permanent effects on all nominal rates. The fast adjustment in yen, mark, Canadian dollar, and pound rates shows evidence of greater price flexibility in those economies and perhaps a higher degree of substitutability between national outputs. Lengthier adjustment periods among the lira, peso, and cruzeiro rates are associated with extensive depreciations in those currencies over the floating exchange rate period. More may be said with regard to price flexibility, degree of substitutability, and whether the model captures the effects of demand or income disturbances by studying real rate responses.

See Figures 2.1B-2.8B. Any nonzero real rate response is a violation of PPP (lack of substitutability) and evidence of sticky prices. All real rates overshoot long run responses to nominal shocks as they are restricted to do so by the long run identifying restriction. The yen, mark, and pound rates fail to move much at impact due to the nominal shock and adjust quickly thereafter. The franc, peso, and cruzeiro rates show sizable impact responses and take thirty-six months or more to adjust. Recalling the comments on PPP where comparing nominal and real rates lead to the conclusion that PPP performed well in Argentinean and Brazilian data raises a puzzle. Shocks to peso and cruzeiro rates show greater persistence than those to the G-7 rates. This means that observing the long run performance of PPP takes more than three years and probably that monetary disturbances are more important in the highly inflationary economies than in the G-7.

Most real rate responses to the real shock mimic the predicted response to a negative demand disturbance, as in the once and for all appreciations of the yen, mark, and pound rates. If the real shock captures the effects of a demand disturbance, nominal and real rate responses to it are a priori identical. This is the case for the yen, mark, and pound rates. Where responses are nonconstant over time, the implication is that income disturbances are at work.

Forecast error variance decompositions assess the relative importance of nominal and real shocks to nominal and real exchange rate fluctuations.[9] Tables 2.1 - 2.8 report exchange rate forecast error variance decompositions. Real shocks are relatively important to nominal rate movements in a majority of cases. The percent of nominal rate forecast error variance due to nominal shocks ranges from a low of 0.58 for Brazil to a high of 98.83 for Argentina. Among the G-7, nominal shocks account for a low of 0.82% of mark rate movements to a high of 57.98% of Canadian dollar movements. The relative importance of shocks is constant as forecast horizon increases among the G-7. Nominal shocks become less important to errors in forecasting the peso and more important to errors in forecasting the cruzeiro as horizon increases.

I offer two interpretations of the greater relative importance of real shocks to nominal rates. First, if foreign exchange markets efficiently process information then the effects of future events are accounted for in the current nominal rate. Given that errors in forecasting future nominal rates are generally not attributable to nominal shocks, foreign exchange market participants appear to be adept at understanding the course of changes in money supplies and their long run effects. The greater relative importance of nominal shocks to the nominal peso rate may indicate a lack of market efficiency in the determination of that currency price. Second, monetary disturbances are certainly less prevalent in the G-7 economies compared to the Argentinean and Brazilian economies. This is to the credit of the Blanchard and Quah method. Where monetary disturbances predominate, as in the Argentinean economy, the empirical method detects a greater relative importance of nominal shocks.[10]

Real shocks contribute to the vast majority of real rate forecast error variances except for the real peso rate. Real shocks account for at least 90% of error variances in forecasting the real yen, mark, lira, and pound rates at all horizons. The greater relative importance of real shocks is constant over low to high horizons with the exception of the real Canadian dollar rate where nominal shocks become somewhat more important as horizon increases. The greater relative importance of nominal shocks to the real peso rate attests to the prevalence of monetary disturbances in the Argentinean economy. And let me reiterate that to its credit, the Blanchard and Quah method identifies the greater relative importance of nominal shocks in economies where they predominate.

How do these results compare to those reported by Lee and Enders for the cases of Japan, Germany, and Canada? Recall the above discussion on model identification. In addition to restricting the long run response of the real rate to a nominal shock to be zero, Lee and Enders overidentified their working model by assuming the impact response of the real rate to a nominal shock to be zero. Theoretical nominal and real rate responses equal eachother at impact due to sticky prices. Nevertheless Lee and Enders fail to reject the restriction imposed on the VAR by the overidentifying restriction. Their real rate impulse response functions due to a nominal shock show zero impact responses. Otherwise their results are similar. They describe fast speed of adjustment in response to both shocks, liken responses to a real shock to that of a demand disturbance, and uncover a greater relative importance of real shocks. My extension shows that the results are not sensitive to overidentification and that the Blanchard and Quah method is capable of detecting a greater relative importance of nominal shocks in economies where monetary disturbances predominate.

The question of whether the empirical model is sensitive to the variables in it deserves addressing. Given the above results on nominal rate behavior, do we get similar results when the nominal rate is modeled with output? The answer is no. Table 1 gives VAR lag length test results for $X_t = [\Delta e_t, \Delta y_t]'$.[11] Figures 3.1A-3.6A show nominal rate impulses from the bivariate model of the change in the nominal rate and the change in output among the G-7. All nominal rates increase at impact due to a positive nominal shock. The nominal values of the yen, Canadian dollar, and pound immediately jump to their long run responses. The nominal value of the franc overshoots, the nominal values of the mark and lira undershoot. Nominal rates generally adjust quickly to nominal shocks. The responses are consistent with those to a positive monetary disturbance. Positive real shocks generate depreciations in the yen, mark, and lira. Positive real shocks generate appreciations in the Canadian dollar, franc, and pound. However the responses are close to zero in all cases. Note in passing that, in contrast to results from the bivariate models of the change in the nominal rate and the change in the real rate, nominal rate responses to nominal shocks exceed those to real shocks.

Figures 3.1B-3.6B show output responses. The Dornbusch model predicts monetary disturbances to have temporary effects on output and demand disturbances to have no effects at all. The nominal shock is restricted to have a temporary effect on output. Output impulse response functions help determine whether the nominal shock captures the a priori temporary effect of a monetary disturbance or the a priori nonexistent effect of a demand disturbance. A positive nominal shock raises Japanese, Canadian, and French output levels. A positive nominal shock lowers German, Italian, and U.K. output levels. Overshooting necessarily occurs due to the long run restriction. Output levels quickly adjust to the nominal shock. Although the nominal shock generates small short run movements in output levels, the presence of such movements suggests the effects of a monetary disturbance and not a demand disturbance.

All countries' output levels immediately increase in response to a positive real shock, and generally overshoot long run responses. Output levels adjust to real shocks within six months. These responses capture the permanent effects of theoretical income disturbances.

Tables 3.1-3.6 give variance decompositions. The decompositions of nominal rate forecast error variances reflect the greater nominal rate responses to nominal shocks than to real shocks seen in the impulse response functions. Nominal shocks account for at least 97% of nominal rate forecast error variances at all horizons. The greater relative importance of nominal shocks to nominal rate movements remains constant as horizon increases. Real shocks account for at least 98% of output forecast error variances at all horizons and their relative importance also remains constant as horizon increases.

When the change in the nominal rate is modeled with the change in the real rate, real shocks are relatively important to nominal rate fluctuations. However when the change in the nominal rate is modeled with the change in output, nominal shocks are relatively important to nominal rate fluctuations. Speaking strictly within the confines of the empirical method, a shock with temporary effects on the real rate is unimportant to nominal rate movements whereas a shock with temporary effects on output is very important to nominal rate movements. One decomposition of the nominal rate is misleading. Decomposing the nominal rate, the real rate, and output in recognition of monetary, demand, and income disturbances may shed light on the correct bivariate decomposition.

4.4 Trivariate Results

The trivariate version of the empirical model recognizes one nominal shock and two real shocks. Hence a better opportunity to distinguish between demand and income disturbances arises. Results will also shed light on the question of which bivariate model gives the more genuine results.

Table 1 reports lag length test results for the trivariate time series of first differences of exchange rates and output. Adding the change in output to the vector of the changes in exchange rates alters only lag length on Canada's VAR.[12]

Recall the overidentification restriction employed to identify the trivariate version of the empirical model. The overidentifying restriction assumes that three impact responses equal zero. They are the real rate impact response to the nominal shock, the output impact response to the nominal shock, and the output impact response to the first real shock. Overidentification imposes three restrictions on a VAR. In words, overidentification restricts the cumulative effects of lagged changes in the nominal rate on the change in the real rate to be zero, and restricts the cumulative effects of lagged changes in both the nominal rate and real rate on the change in output to be zero. In the notation of 3.2, overidentification imposes the following restrictions on a VAR: $A_{21}(L=1) = A_{31}(L=1) = A_{32}(L=1) = 0$.

Imposing overidentification restrictions means that the regressors in each equation of the VAR will differ. Thus the VARs are estimated as SUR models in order to reap a possible gain in efficiency. Table 4 gives the overidentification test results. The null of overidentification cannot be rejected except in the case of France. Generally failing to reject overidentification suggests that what we are about to see is similar to results from (expensively) just identified models. Rejecting overidentification with the French data suggests that the procedure detects something unique to that case. Perhaps comparing the case of France to the others will indicate the cost of overidentification when it is unwarranted.

Recall that the nominal shock is intended to capture the effects of a monetary disturbance. The first real shock is intended to capture the effects of a demand disturbance. And the second real shock is intended to capture the effects of an income disturbance. The identification procedure restricts the nominal shock to temporarily affect levels of the real rate and output. Identification restricts the first real shock to temporarily affect the level of output in order to investigate the a priori nonexistent effect of a demand disturbance on output.

Begin with impulse response functions pictured in Figures 4.1A-4.6A. Each shock's effect on the nominal rate is unrestricted. The nominal values of all currencies immediately and permanently depreciate in response to a positive nominal shock as though the shock were a domestic monetary disturbance. Incidentally, one may wonder why the empirical model never characterizes the opposite effect of a foreign monetary disturbance given that it is free to do so. The majority of the nominal rates respond to positive nominal shocks by jumping once and for all to the long run response. Only the nominal lira rate undershoots and takes about twenty four months to complete adjusting.

The first real shock has the greatest impact on nominal rates. Nominal values of all currencies immediately and permanently depreciate in response to a positive real shock of the first type. The yen, mark, Canadian dollar, and pound rates immediately depreciate to the long run response. The franc and lira nominal rates overshoot and undershoot, respectively. Nominal rates generally adjust quickly to the first real shock. The lira rate adjusts slowly to the first real shock, over a twenty four month period.

All nominal rates jump once and for all to long run values, in response to positive real shocks of the second type. These short and long run responses induced by the second real shock are barely above or below zero, however. This result explains the contrast in bivariate results from modeling the change in the nominal rate with the change in the real rate, compared to modeling the change in the nominal rate with the change in output. The first real shock, intended to capture the effects of a demand disturbance, has a big impact on nominal rates. The second real shock, intended to capture the effects of an income disturbance, has a small impact on nominal rates. The implication is that a bivariate model of the nominal and real rates captures the effects of a demand disturbance. The bivariate model of the nominal rate and output captures the effects of an income disturbance.

Figures 4.1B-4.6B present real rate responses to positive impulses. They show one cost of overidentification, namely suppressing some short run behavior in real rates. Real rate responses at impact due to the nominal shock are restricted to be zero. Where the working model is based on a first order VAR, all responses thereafter will be zero too. Nevertheless the pictures show that nominal shocks generate little activity. For example, even in the cases of the real mark, franc, and lira rates, where after-impact responses may deviate from zero, they show no tendency to do so. Thus, short run behavior suppressed by overidentification appears unimportant.[13]

The first real shock generates the largest movements in real rates. The real values of all currencies immediately and permanently depreciate in response to a positive shock of the first real type, as though the shock were a negative demand disturbance. Adjustment is fast: most real rates jump once and for all to long run responses. The real franc rate overshoots but still adjusts within about six months. The regularity of fast adjustment coupled with similar nominal rate responses to the first real shock make a strong case that the first real shock captures the effects of a demand disturbance. Note in passing that the second real shock induces no activity in real rates.

Output responses to impulses from nominal and first real shocks, shown in Figures 4.1C-4.6C, are restricted at impact to be zero. Nevertheless the cost of suppressing that short run behavior in output levels in order to identify the working model seems to be low, given the apparent lack of response activity over the long run. Also notice that while theory rules out the effects of demand disturbances on output, the first real shock is allowed to temporarily affect output levels. The small responses of output to the first real shock appear to mimic the a priori nonexistent effects of a demand disturbance.

Impulses from the second real shock generate the large responses in output levels. All output levels immediately and permanently increase in response to a positive shock of the second real type. Such behavior suggests the response to an income disturbance. Impact responses generally overshoot long run responses, with the exception of U.K. output which appears to adjust once and for all. Output levels quickly adjust to the second real shock, within three to six months. Given that theory recognizes permanent output movements arising only from income disturbances, it seems reasonable to liken the second real shock to an income disturbance.

Recall the issue of potentially misleading bivariate results in the presence of multiple disturbances. Appendix B provides the necessary and sufficient conditions for bivariate results to not be misleading. Impulse response functions obtained from the trivariate model, Figures 4.1A-4.6C, help determine which set of bivariate results are or are not misleading in the presence of one nominal shock and two real shocks.

Consider the bivariate results from modeling nominal and real exchange rates. In order for that decomposition to not be misleading, the dynamic responses of the nominal rate to the first real shock must be similar to the dynamic responses of the real rate to the first real shock, and the dynamic responses of the nominal rate to the second real shock must be similar to the dynamic responses of the real rate to the second real shock. Trivariate results indicate that these conditions seem to be met. Nominal and real rate responses to the first real shock are generally one time jumps. Nominal and real rate responses to the second real shock are essentially zero. The bivariate decomposition of nominal and real rates, which ignores one of two a priori real disturbances, appears meaningful.

The same cannot be said for the bivariate decomposition of the nominal rate and output. Trivariate results show that the dynamic responses of the nominal rate to the second real shock are not similar to the dynamic responses of output to the second real shock. Nominal rates exhibit near-zero impact responses to the second real shock, and do not deviate much from zero thereafter. Output responses to the second real shock, however, generally exhibit overshooting. Thus the bivariate decomposition of the nominal rate and output is misleading.

Variance decompositions in Tables 5.1-5.6 explain the relative importance of each shock to each time series in the trivariate model. Variation in each time series is clearly dominated by a single shock. The first real shock accounts for at least 76% of nominal exchange rate forecast error variances. The nominal shock contributes from a low of about 2% to errors in forecasting the nominal franc rate, to a high of about 23% to errors in forecasting the Canadian dollar nominal rate. Virtually no errors in forecasting nominal rates are attributable to the second real shock.

The first real shock explains at least 90% of real exchange rate forecast error variances. The nominal shock manages to account for up to 4.5% of real franc fluctuations at high horizons, but is otherwise unimportant. The second real shock accounts for virtually no movements in real rates, as with the nominal rate.

The second real shock does play an important role in output movements. It accounts for nearly 100% of output movements for all countries and over all horizons. The temporary effects of the nominal shock and first real shock evidently contribute nothing to output variation.

To summarize, the first real shock dominates nominal and real exchange rate time series and the second real shock dominates output time series. The implication is that monetary disturbances are unimportant to these macroeconomic variables among the G-7 economies. Demand disturbances are the primary source of permanent nominal and real exchange rate fluctuations. Income disturbances are the primary source of permanent output movements. Temporary variations in real rates and output are minor if not nonexistent.

CHAPTER 5
CONCLUSION

5.1 Summary

The introduction set forth the proposition relating an exchange rate to price levels known as PPP. Fluctuations in the real exchange rate determine the extent to which PPP prevails. Past empirical evidence suggests that PPP does not perform well. Given the lack of strong performance in PPP, the proposition was cast into the monetary approach to exchange rate determination which allows for deviations from it. A simple model of the flexible price monetary approach to exchange rate determination illustrates the role of monetary, demand, and income disturbances to exchange rate behavior, but does not allow for differences between contemporaneous and long run adjustments to those disturbances. Thus the study adopted the sticky price monetary approach in order to consider the possibility of exchange rate and output overshooting.

Studies of exchange rate behavior often employed univariate time series methods. However Buiter claims that exchange rate behavior such as overshooting is only appropriately studied in the context of bivariate analysis.

Moreover Quah's theoretical results on permanent and transitory decompositions of a single time series uncover fairly substantial limitations. Thus this study adopted the bivariate empirical model by Blanchard and Quah.

The bivariate decompositions of nominal and real exchange rates give various important results. Fast speed of exchange rate adjustment indicates a high degree of price flexibility among the G-7 economies. Slow speed of adjustment occurs in the cases of Italy and Argentina whose currencies underwent prolonged depreciations over the current period of exchange rate floating. Many nominal and real rates adjust once and for all to impulses from nominal and real shocks which supports price flexibility and casts doubt upon overshooting. In fact, more nominal and real rates undershoot than overshoot long run responses. High degrees of income elasticity of money demand and substitutability between national outputs explain undershooting among the G-7. As for Argentina, undershooting probably indicates the failure of UIP and the necessary role the current account must then play in order to equilibrate the balance of payments.

The Blanchard and Quah identification procedure restricts the nominal shock to capture the effects of a monetary disturbance. According to impulse response functions, the real shock appears to capture the effects of a demand disturbance. Variance decompositions generally imply a greater relative importance of demand disturbances. Incidentally, variance decompositions of peso rates shows that the Blanchard and Quah method is capable of detecting a greater relative importance of monetary disturbances in economies where they predominate. These findings match those reported by Lee and Enders for Japan, Germany, and Canada and suggest that their overidentification of the empirical model comes at low cost.

Blanchard and Quah recognize the limitation of bivariate decompositions in light of multiple nominal and real shocks. This study's bivariate decompositions of the nominal exchange rate and output provide misleading results. In particular, the relative importance of real shocks to nominal rate fluctuations is reversed from the case of modeling nominal and real rates in a bivariate model. Given that nominal rate and output responses to the real shock are not sufficiently similar, the decomposition of the nominal rate and output is incorrect.

The trivariate decompositions of the nominal rate, real rate, and output confirm the results from the correct bivariate decomposition. The trivariate working model was overidentified. Likelihood ratio tests failed to reject the null hypothesis overidentification imposes on the VAR in all cases but France. Nevertheless results for France are not much different. The implication is that overidentification, which suppresses some immediate real rate and output responses, comes at low cost.

The impulse response functions drawn from the trivariate decomposition suggest that the nominal and two real shocks can reasonably be likened to monetary, demand, and income disturbances, respectively. Variance decompositions show the greater relative importance of demand disturbances to nominal rates, with monetary disturbances playing a small role. The importance of demand disturbances is consistent with the results of Evans (1986), who reports significant effects of government spending on the nominal exchange rate. Flood (1981,p.237) recognizes the possibility that agents who predict nominal rates assuming that the money supply is exogenous, when in reality it is set with discretion, will tend "...to underpredict the extent of exchange-rate volatility." The small relative importance of monetary disturbances weakens this possibility, since variance decompositions show that errors in predicting nominal rates are primarily due to what agents do not know about future demand disturbances.

Demand disturbances also contribute to nearly all real rate movements. Meese and Rogoff (1988) explore the correlation between real exchange rates and real interest rate differentials. They conclude that the role of monetary disturbances in the SPMA fails to explain the real exchange rate behavior. They suggest that the lack of correlation between real exchange rates and real interest rate differentials implied by the SPMA is due real disturbances such as productivity shocks. The present results suggest that if real disturbances explain the lack of correlation between real exchange rates and real interest rate differentials, they are of the demand type.

Output variation is primarily due to income disturbances. The result is consistent with the view from real business cycle models. For example, Kydland and Prescott (1982) attribute disturbances arising from tastes and technology as the source of business cycle activity. As for the results of previous empirical studies, Campbell and Mankiw (1987) find a high degree of persistence in output fluctuations. Cochrane (1988) concludes that if permanent disturbances exist, they are unimportant compared to transitory disturbances. The permanent output responses shown by impulse responses above coupled with the importance of income disturbances shown by variance decompositions are consistent with the results of Campbell and Mankiw.

5.2 On Foreign Exchange Market Intervention

Marston (1985) reviews the literature on the optimal degree of foreign exchange market intervention. Mundell's (1963) results on stabilizing output relate to the extreme cases of fixed versus flexible exchange rates. Monetary disturbances do not affect output under a fixed exchange rate regime. Demand disturbances do not affect output under a flexible exchange rate regime, as in the models above. The implication is that output fluctuations can be reduced in the face of monetary instability by fixing exchange rates, or in the face of demand instability by allowing exchange rates to float.

Glick and Hutchinson (1989) study an open economy in order to determine the optimal degree of foreign exchange market intervention. Their structural model determines interest rate, output, and price level. Monetary policy employs an exchange rate target. Let me rewrite a monetary approach structural model that incorporates an exchange rate target and the above empirical results in order to make comments on the optimal degree of intervention.

Generally fast speed of exchange rate and output adjustment found above supports price flexibility. This puts income at its full employment level. The FPMA structural model becomes as follows.

$$m_t - p_t = k\overline{y}_t - \lambda i_t \quad k,\lambda>0 \qquad (5.2.1)$$

$$i_t = E_t e_{t+1} - e_t \qquad (5.2.2)$$

$$\bar{y}_t = \delta(e_t - p_t) + x_t \quad \delta > 0 \tag{5.2.3}$$

$$m_t = \bar{m} + z_t - \gamma(e_t - p_t) \tag{5.2.4}$$

(5.2.1) is the familiar money demand where k and λ respectively denote income elasticity and interest semielasticity. (5.2.2) is the UIP relation where the foreign interest rate is assumed constant and zero. (5.2.3) is aggregate demand where the foreign price level is assumed constant and zero. Assume that random walks characterize the exogenous processes of full employment income and the demand shift parameter as above: $\Delta\bar{y}_t = u_t$, $\Delta x_t = w_t$.

The discretionary rule (5.2.4) sets the money supply. The monetary authority controls the constant $\bar{m}$. Assume that z_t is a random walk in order to generate permanent effects of monetary disturbances: $\Delta z_t = v_t$. The exchange rate target is its PPP value, namely the price level. Infinite and zero values for γ correspond to fixed and flexible exchange rate regimes, respectively.

The solution procedure is similar to that for the above presentation of the FPMA. The nominal rate and price level reduced forms follow.

$$e_t = \overline{m} + z_t - (k - \frac{1-\gamma}{\delta})\overline{y}_t - \frac{1-\gamma}{\delta}x_t \qquad (5.2.5)$$

$$p_t = \overline{m} + z_t - (k + \frac{\gamma}{\delta})\overline{y}_t + \frac{\gamma}{\delta}x_t \qquad (5.2.6)$$

Price flexibility eliminates the possibility of any exchange rate over or undershooting. The current price level is no longer predetermined in the absence of sticky prices. One may obtain the real exchange rate reduced form and observe that price flexibility removes the temporary effects of monetary disturbances.

Glick and Hutchinson show that the presence of income disturbances forces the monetary authority to choose weights on income and price level stability. Here I have put income at the full employment level based upon empirical evidence attributing income disturbances to income fluctuations. Thus the authority need not offset short run income fluctuations due to monetary or demand disturbances and cannot offset full employment fluctuations.

So suppose the authority seeks to stabilize the inflation rate around some target value. It does so by choosing the optimal degree of foreign exchange market intervention in order to minimize the expected value of a quadratic loss function:

$$E(\Delta p_t - \Delta p^T)^2, \qquad (5.2.7)$$

where Δp^T denotes the target value. The optimal degree of intervention is:

$$\gamma = \frac{-k\delta}{1+\sigma_w^2/\sigma_u^2}. \qquad (5.2.8)$$

Monetary disturbances have no bearing on the optimal degree of intervention due to the zero weight placed on income stability. The intervention parameter's negative value implies that the authority will raise (lower) the money supply in response to nominal exchange rate depreciations (appreciations). Glick and Hutchinson refer to such policies that enhance nominal rate depreciations and appreciations as "leaning with the wind."

The optimal intervention parameter approaches zero from below as demand disturbances become more important. The result reflects the lack of influence demand disturbances will have on the price level in a regime of floating exchange rates. The optimal intervention parameter approaches minus infinity as income disturbances become more important. In this case the authority increasingly manages the nominal exchange rate in order to hit its inflation target.

Intervention in the foreign exchange market in order to hit an inflation target involves a tradeoff. The only benefit derives from experiencing a less volatile inflation rate when income disturbances predominate. The tradeoff is that by intervening, demand disturbances will then influence the price level. The trivariate VAR estimate of the variance of the first real shock (taken to be a demand disturbance) exceeds that of the second real shock (taken to be an income disturbance) in the cases of Japan, Germany, France, and the U.K. The implication is that these countries could achieve greater price stability by never intervening in the foreign exchange market. Canada and Italy, where estimated variances of income disturbances are greater than those of demand disturbances, could achieve greater price stability by more frequent intervention.

Despite the implications to monetary policy stemming from results on the relative importance of macroeconomic disturbances, the aforementioned recommendations must be made and taken with caution. The above model illustrates the well known result (for example Mussa (1979)) that central banks cannot successfully alter nominal exchange rates without altering money supplies. Such intervention is called "unsterilized" and implies that manipulating currency values to stabilize one variable may come at the cost of sacrificing stability of some other variable. For example, the monetary authority's goal of targeting inflation, given what it knows about the importance of macroeconomic disturbances, may raise the relative importance of monetary disturbances and destabilize output. Glick and Hutchinson point out another important qualification: the extent to which the nominal exchange rate can be used as a instrument for stabilization is limited by the strong possibility that policymakers cannot distinguish among monetary and real disturbances.

5.3 Extension

Takagi (1991) cites the lack of empirical evidence finding any significant correlation between exchange rates and interest rates. He puts forth an open economy model assuming that agents with imperfect information cannot distinguish between monetary and real disturbances. Imperfect information explains an ambiguous sign on the covariance between the nominal exchange rate and the nominal interest rate. His theoretical result and the greater relative importance of demand disturbances found above, imply that the lack of significant correlation between exchange rates and interest rates is due to agents' mistaking demand disturbances for monetary disturbances.

Extending the above results would shed light on Takagi's idea. The extension entails testing for a cointegrating relationship between nominal exchange rates and nominal interest rates. If no such relationship exists, a bivariate version of the Blanchard and Quah empirical model may be identifiable for the nominal exchange rate and interest rate. One could then study covariation between the nominal exchange rate and nominal interest rate by inspecting impulse response functions to nominal and real shocks. Studying covariation between the real exchange rate and real interest rate also has a place in such an extension.

ENDNOTES

1. Covered interest parity (CIP) implies UIP where covered and uncovered indicates the trader's position in the foreign exchange market. Suppose a trader has x units of domestic currency with which to buy bonds. If the trader buys domestic bonds then the future value after one year is: $x(1+i_t)$. The trader compares that future value to one obtained from buying foreign bonds.

Suppose the trader buys a foreign bond. To do so, the trader converts the x units of domestic currency into $x(1/S_t)$ units of foreign currency, where S_t denotes the spot price of foreign currency (the antilog of e_t in current chapter). The trader maintains a closed position by simultaneously buying the domestic currency equivalent of the future value at the current forward rate, F_t. In this case the future value is: $x(1+i_t^*)(F_t/S_t)$. Arbitrage equates future values so that $(1+i_t) = (1+i_t^*)(F_t/S_t)$. Taking natural logs of both sides and using the log approximation gives: $i_t - i_t^* = f_t - s_t$, where lower case letters denote log values of upper case counterparts. The last equality is the CIP relation.

The trader maintains an open position by buying the domestic currency equivalent of the future value at the expected future spot rate, $E_t s_{t+1}$. Substituting the expected future spot rate into the CIP relation gives the UIP relation: $i_t - i_t^* = E_t s_{t+1} - s_t$.

2. Sargent (1987, p.395) distinguishes between backshift (B) and lag (L) operators. The backshift and lag operators do not and do, respectively, alter information sets. I.e., compare $BE_t e_{t+1} = E_t e_t$ to $LE_t e_{t+1} = E_{t-1} e_t$.

3. Empirical evidence justifies assuming difference stationarity of nominal and real exchange rates. Meese and Singleton (1983) fail to reject the null of a unit root in nominal rates. Enders (1988) fails to reject the null of a unit root in real rates.

4. To see the implication, and become familiar with the notation, assume for the moment that only nominal shocks are present. Let

$$\Delta r_t = C_{21}(L)\eta_{nt} = \sum_{i=0}^{\infty} C_{21}(i)\eta_{nt-i}.$$

Obtain the representation for r_t:

$$r_t = (1-L)^{-1}\sum_{i=0}^{\infty} c_{21}(i)\eta_{nt-i}$$
$$= c_{21}(0)\eta_{nt} + (c_{21}(0)+c_{21}(1))\eta_{nt-1} + \cdots$$
$$= \sum_{j=0}^{\infty} [\sum_{i=0}^{j} c_{21}(i)]\eta_{nt-j}.$$

It follows that the long run response to a money disturbance is

$$\lim_{j\to\infty}\frac{\partial r_{t+j}}{\partial \eta_{nt}} = \sum_{i=0}^{\infty} c_{21}(i) = C_{21}(L=1).$$

5. If nominal and real exchange rates are difference stationary and a cointegrating (or equilibrium) relationship exists between them, a finite order VAR representation of the first differences does not exist. I.e., if e_t and r_t are C(1,1) processes then a finite order VAR representation of $[\Delta e_t, \Delta r_t]'$ does not exist. See Campbell (1987).

Empirical evidence casts doubt upon the possibility of an equilibrium relationship. Huizinga concludes that no cointegrating relationships exist between nominal and real rates and between real rates and output levels. Thus the existence of a finite order VAR representation of the first differences of these time series is reasonable to assume.

6. Lee and Enders assume that C(0) is triangular, i.e., $c_{21}(0) = 0$. Triangularity makes solving for C(0) easier but is in fact an overidentifying restriction. The empirical consequences of overidentifying the working model are addressed below.
As far as other identification strategies, one might attempt to identify C(0) by imposing more long run restrictions and dropping the same number of variance restrictions. For example, one might appeal to the predicted equiproportionate effect of a monetary disturbance on the nominal exchange rate, assume $C_{11}(L=1) = 1$, and drop one variance restriction. However such a scheme and others like it fail to yield real solutions for C(0).

7. One estimates unrestricted and restricted VARs. The null hypothesis is that the number of lag lengths is that in the restricted VAR. The test statistic is: $\chi^2 = (T-c)[\ln|\Sigma_r| - \ln|\Sigma_u|]$. T denotes number of observations (equal across unrestricted and restricted models). c denotes Sims' multiplier correction equal to the number of variables in each unrestricted equation. $\ln|\Sigma_r|$ and $\ln|\Sigma_u|$ denote natural log values of the determinants of the estimated covariance matrices for restricted and unrestricted models, respectively.

One could also choose lag length by using Aikaike Information Criterion (AIC) or Bayesian Information Criterion (BIC). Granger and Newbold (1986) discuss the procedure. One may choose the order of a VAR, p, as the value that minimizes AIC = $\ln|\Sigma_p|+2pm^2/T$ or BIC = $\ln|\Sigma_p|+\ln(T)pm^2/T$, where m denotes the number of equations in the VAR. The BIC imposes the cost of losing observations with higher order models. When a higher order model is considered, the log likelihood function must drop by more in the BIC than in the AIC due to the ln(T) term in the BIC.

8. Granger causality tests indicate whether lagged values of one time series are useful for explaining the current value of another. Recall the notation for the VAR of 3.2:

$$X_t = A(L)X_{t-1} + \epsilon_t,$$

where $X_t = [\Delta e_t, \Delta r_t]'$. Null hypotheses are H_0: $A_{ij}(L) = 0$, for each pair i,j = 1,2. For example, the null that lagged changes in the nominal rate fail to explain the current change in the nominal rate is: H_0: $A_{11}(L) = 0$.

I fail to reject that nominal rate and real rate changes do not Granger-cause the change in the nominal rate in G-7 data, but not in Argentinean and Brazilian data. I fail to reject that nominal rate and real rate changes do not Granger-cause the change in the real rate in all but Canadian data. The results are consistent with the random walk behavior of nominal rates among G-7 countries, and the random walk behavior of real rates among all countries.

Generally failing to reject that nominal and real rates are not useful for explaining future movements in either time series, one may question the suitability of a bivariate model for nominal and real rates. This lead me to test the null of zero lags on the VAR versus the alternative of one lag, and versus the alternative of lag length chosen according to the Sims test. The data rejects the null of zero lags on the VAR versus one or the other alternative in all cases but the U.K. Thus even in cases where I cannot reject H_0: $A_{ij}(L) = 0$ for each pair i,j, I can reject H_0: $A_{ij}(L) = 0$ for all pairs i,j. Put differently, the bivariate model is suitable for investigating dynamic behavior not captured by random walk models.

9. Specifically, a decomposition gives the percentages of forecast error variance attributable to the different types of future disturbances in the time series at various forecast horizons. Suppose one intends to forecast future levels of the nominal rate. Using the notation from 3.2, the representation for the level of the nominal rate is:

$$e_t = D_{11}(L)\eta_{nt} + D_{12}(L)\eta_{rt},$$

where $D_{ij}(L) = (1-L)^{-1}C_{ij}(L)$, i,j = 1,2. The forecast of the nominal rate h periods into the future (horizon h), conditional on current information is:

$$E_t e_{t+h} = d_{11}(h)\eta_{nt} + d_{11}(h+1)\eta_{nt-1} + \cdots$$
$$+ d_{12}(h)\eta_{rt} + d_{12}(h+1)\eta_{rt-1} + \cdots.$$

The forecast error is:

$$e_{t+h} - E_t e_{t+h} = \sum_{i=0}^{h-1} d_{11}(i)\eta_{nt+h-i} + \sum_{i=0}^{h-1} d_{12}(i)\eta_{rt+h-i}.$$

The forecast error variance is:

$$V\{e_{t+h}-E_t e_{t+h}\} = \sum_{i=0}^{h-1} d_{11}(i)^2 + \sum_{i=0}^{h-1} d_{12}(i)^2,$$

where the disturbances have unit variances and are uncorrelated. The forecast error variance due to nominal shocks at horizon h is:

$$\sum_{i=0}^{h-1} d_{11}(i)^2 / V\{e_{t+h}-E_t e_{t+h}\}.$$

The forecast error variance due to real shocks at horizon h is 1 minus the above.

10. This leaves counter intuitive results for Brazil. According to Figure 2.8A, both nominal and real shocks appear to trigger infinite depreciations in the nominal cruzeiro rate. Such responses suggest nonstationarity. Given the estimated autoregressive polynomial in the lag operator on $X_t = [\Delta e_t, \Delta r_t]'$, we can evaluate it at one and invert it. Using the notation of 3.2, and rounding off to two decimal places, the result is:

$$B(L=1) = [I-A(L=1)]^{-1} = \begin{bmatrix} 45.08 & -27.00 \\ 1.76 & -0.12 \end{bmatrix}.$$

Thus the VAR must be noninvertible and the results on Brazilian data are not useful.

11. For $X_t = [\Delta e_t, \Delta y_t]'$, Granger causality tests generally fail to reject that lagged changes in the nominal rate do not explain the current change in the nominal rate. Lagged changes in output generally fail to explain the change in the nominal rate. The results are consistent with random walk nominal rates. Lagged changes in the nominal rate fail to explain the current change in output, but lagged changes in output do explain the current change in output. So output levels differ from random walks.
As to the suitability of using a bivariate model for $X_t = [\Delta e_t, \Delta y_t]'$, I reject the null of zero lags on the VARs versus either the alternative of one or the alternative of lag length chosen according to the Sims test in all cases but the U.K. The

bivariate model seems appropriate relative to random walk models.

12. Granger causality tests from the trivariate model are similar to those reported in above notes from the bivariate models. Lagged changes in the nominal rate, real rate, and output generally do not explain the current change in the nominal rate. Lagged changes in the nominal rate, real rate, and output generally do not explain the current change in the real rate. These results reflect the random walk behavior of nominal and real rates. Lagged changes in the nominal rate and real rate generally fail to explain the current change in output, but I can reject that lagged changes in output do not explain the current change in output. Output levels do not follow random walks.

I can reject the null of zero lags on the trivariate VARs versus the alternative of one lag and the alternative of lags chosen according to the Sims test in all cases but the U.K. Thus the trivariate model of $X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$ seems appropriate.

13. Recall that the French data rejected overidentification. Theoretical nominal and real rate responses to each shock equal eachother at impact, due to sticky prices. The nominal franc rate immediately depreciates somewhat due to a positive nominal shock. If the real franc responds similarly to a positive nominal shock, perhaps overidentification is rejected for this reason.

WORKS CITED

Adler, Michael and Bruce Lehmann. "Deviations from Purchasing Power Parity in the Long Run." The Journal of Finance 38 (December 1983): 1471-1487.

Blanchard, Olivier and Danny Quah. "The Dynamic Effects of Aggregate Demand and Supply Disturbances." American Economic Review 79 (September 1989): 655-73.

Buiter, Willem. "Comment on the Huizinga Paper." Carnegie-Rochester Conference Series on Public Policy 27 (1987): 215-223.

Campbell, John Y. "Does Saving Anticipate Declining Labor Income? An Alternative Test of the Permanent Income Hypothesis." Econometrica 55 (November 1987): 1249-73.

Campbell, John Y. and Gregory Mankiw. "Are Output Fluctuations Transitory." Quarterly Journal of Economics 102 (1987): 857-90.

Cassel, Gustav. "The Present Situation of the Foreign Exchanges." Economic Journal 26 (March 1916): 52-5.

Cochrane, John H. "How Big is the Random Walk in GNP?" Journal of Political Economy 96 (1988): 893-920.

Cowitt, Philip P. World Currency Yearbook. Brooklyn: International Currency Analysis, Inc., 1989.

Dornbusch, Rudiger. "Expectations and Exchange Rate Dynamics." Journal of Political Economy 84 (1976): 1161-76.

Enders, Walter. "ARIMA and Cointegration Tests of PPP Under Fixed and Flexible Exchange Rates." Review of Economics and Statistics (August 1988): 504-08.

Evans, Paul. "Is the Dollar High Because of Large Budget Deficits?" Journal of Monetary Economics. 18 (1986): 227-49.

Fama, Eugene F. and Kenneth R. French. "Permanent and Temporary Components of Stock Prices." Journal of Political Economy 96 (1988): 246-273.

Flood, Robert P. "Explanations of Exchange-Rate Volatility and Other Empirical Regularities in Some Popular Models of the Foreign Exchange Market." Carnegie-Rochester Conference Series on Public Policy 15 (1981): 219-50.

Frankel, Jeffrey A. "On the Mark: a Theory of Floating Exchange Rates Based on Real Interest Rate Differentials." American Economic Review 69 (1979): 601-622.

________. "Monetary and Portfolio Balance Models of Exchange Rate Determination." In Economic Interdependence and Flexible Exchange Rates, J.S. Bhandari and B.H. Putnam, eds. MIT Press, (1983).: 84-115.

Frenkel, Jacob A. "A Monetary Approach to the Exchange Rate: Doctrinal Aspects and Empirical Evidence." Scandinavian Journal of Economics 78, (1976): 200-224.

Frenkel, Jacob A. and Carlos A. Rodriguez. "Exchange Rate Dynamics and the Overshooting Hypothesis." IMF Staff Papers (1982): 1-30.

Froot, Kenneth A. and Richard Thaler. "Anomalies: Foreign Exchange." Journal of Economic Perspectives 4 (Summer 1990): 179-192.

Fuller, Wayne A. Introduction to Statistical Time Series. New York: John Wiley & Sons, 1976.

Glick, Reuven and Michael Hutchison. "Exchange Rates and Monetary Policy." In Federal Reserve Bank of San Francisco Economic Review (Spring 1989): 17-29.

Granger, C.W.J. and Paul Newbold. Forecasting Economic Time Series. San Diego: Academic Press, Inc., 1986.

Huizinga, John. "An Empirical Investigation of the Long-Run Behavior of Real Exchange Rates." Carnegie-Rochester Conference Series on Public Policy 27 (1987): 149-214.

International Monetary Fund. International Financial Statistics. various issues.

Isard, Peter. "How Far Can We Push the 'Law of One Price?'" American Economic Review 67 (1977): 942-8.

Kravis, Irving B. and Robert E. Lipsey. "Price Behavior in the Light of Balance of Payments Theory." Journal of International Economics 8 (May 1978): 397-407.

Kydland, Finn E. and Edward C. Prescott. "Time to Build and Aggregate Fluctuations." Econometrica 50 (November 1982): 1345-70.

Lee, Bong-Soo and Walter Enders. "Accounting for Real and Nominal Exchange Rate Movements." manuscript, University of Minnesota (1991).

Macdonald, Ronald. Floating Exchange Rates. London: Unwin Hyman, 1988.

Marston, Richard C. "Stabilization Policies in Open Economies." In Handbook of International Economics, vol. 2, R.W. Jones and P.B. Kenen, eds. Amsterdam: Elsevier Science Publishers B.V. (1985): 859-916.

McCallum, Bennett T. "On 'Real' and 'Sticky Price' Theories of the Business Cycle." Journal of Money, Credit, and Banking 18 (November 1986): 397-414.

Meese, Richard and Kenneth Rogoff. "The Out-of-Sample Failure of Exchange Rate Models: Sampling Error or Misspecification?" In Exchange Rates and International Macroeconomics, J.A. Frenkel, ed. Chicago: The University of Chicago Press. (1983): 67-105.

________. "Was it Real? The Exchange Rate-Interest Differential Relation over the Modern Floating-Rate Period." The Journal of Finance 43 (September 1988): 933-48.

Meese, Richard A. and Kenneth J. Singleton. "On Unit Roots and the Empirical Modeling of Exchange Rates." The Journal of Finance 37 (September 1982): 1029-1035.

Mundell, R. A. "Capital Mobility and Stabilization Policy under Fixed and Flexible Exchange Rates." Canadian Journal of Economics and Political Science (1963): 475-85.

Mussa, Michael. "Empirical Regularities in the Behavior of Exchange Rates and Theories of the Foreign Exchange Market." Carnegie-Rochester Conference Series on Public Policy 11. (Autumn 1979): 9-57.

Mussa, Michael. "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates." Carnegie-Rochester Conference Series on Public Policy 25 (Autumn 1986): 117-214

Officer, Lawrence H. Purchasing Power Parity and Exchange Rates. Greenwich, Connecticut: JAI Press, Inc., 1982.

Okun, Arthur M. Prices and Quantities: A Macroeconomic Analysis. Washington, D.C.: The Brookings Institution, 1981.

Pick, Franz. Pick's Currency Yearbook. New York: Pick Publishing Corp., 1981.

Quah, Danny. "The Relative Importance of Permanent and Transitory Components: Identification and Some Theoretical Bounds." manuscript, MIT (1989).

Roll, Richard. "Violations of Purchasing Power Parity and Their Implications for Efficient International Commodity Markets." In M. Sarnat and G. Szego, eds., International Finance and Trade 1. Cambridge, MA: Ballinger, (1979): 133-76.

Sargent, Thomas J. Macroeconomic Theory. Boston: Academic Press, Inc., 1987.

Sims, Christopher A. "Macroeconomics and Reality." Econometrica 48 (January 1980): 1-48.

Stockman, Alan C. "The Equilibrium Approach to Exchange Rates." Federal Reserve Bank of Richmond, Economic Review 73 (March-April 1987): 12-30.

Takagi, Shinji. "Imperfect Information and the Comovement of the Exchange Rate and the Interest Rate: a Signal Extraction Approach." International Economic Review. (November 1991): 1023-1035.

APPENDIX A

MODEL SOLUTTION

Recast the model assuming the foreign price level and interest rate are zero.

$$m_t - p_t = y_t - i_t \tag{A1}$$

$$i_t = E_t e_{t+1} - e_t \tag{A2}$$

$$y_t = \delta(e_t - p_t) - i_t + x_t \tag{A3}$$

$$p_{t+1} - p_t = \phi(y_t - \bar{y}_t) \tag{A4}$$

Obtain the price level and output as functions of the exchange rate, interest rate, and exogenous processes; substitute the results and the interest rate into the demand for money (A1) and rearrange to get

$$\begin{aligned}&[(2+\delta)(1-L)+\phi L+2\delta\phi L]e_t - [2(1-L)+\phi L+\delta\phi L]E_t e_{t+1} \\ &= [1-(1-\delta\phi)L]m_t - [1-L+\phi L]x_t + \phi(1-\delta)L\bar{y}_t.\end{aligned} \tag{A5}$$

Let z be the right hand side of the above equality and rearrange again.

(A6)

Solving (A6) for the exchange rate forecast gives the crux of the solution. Sargent (1987, p.395) solves a similar problem. Taking expectations of each side conditional upon information at time t-1 gives

$$\begin{aligned}-2E_{t-1}e_{t+1} + (4+\delta-\phi-\delta\phi)E_{t-1}e_t - (2+\delta-\phi-2\delta\phi)E_{t-1}e_{t-1} \\ =E_{t-1}z_t.\end{aligned} \tag{A7}$$

Dividing each side by -2 and employing the backshift operator gives

$$B^{-1}E_{t-1}e_t - \frac{4+\delta-\phi-\delta\phi}{2}B^{0}E_{t-1}e_t + \frac{2+\delta-\phi-2\delta\phi}{2}BE_{t-1}e_t = -\frac{1}{2}E_{t-1}z_t \ . \tag{A8}$$

Multiplying each side by the backshift operator, which does not alter information sets, and rearranging gives a second order difference equation for the exchange rate forecast:

$$\left\{ 1 - \frac{4+\delta-\phi-\delta\phi}{2}B + \frac{2+\delta-\phi-2\delta\phi}{2}B^{2} \right\}E_{t-1}e_t = -\frac{1}{2}E_{t-1}z_{t-1} \ , \tag{A9}$$

or equivalently,

$$(1-\rho_1 B)(1-\rho_2 B)E_{t-1}e_t = -\frac{1}{2}E_{t-1}z_{t-1} \ , \tag{A10}$$

where

$$\begin{aligned} \rho_1 + \rho_2 &= \frac{4+\delta-\phi-\delta\phi}{2} \\ \rho_1\rho_2 &= \frac{2+\delta-\phi-2\delta\phi}{2} \\ \Rightarrow \delta\phi &= 2(1-\rho_1)(\rho_2-1) \ . \end{aligned} \tag{A11}$$

It can be shown that the roots satisfy $0<\rho_1<1$ and $\rho_2>1$. Hence ρ_2 can be solved forward in (A10). Doing so gives the exchange rate forecast equation,

$$\begin{aligned} (1-\rho_1 B)E_{t-1}e_t &= \frac{1}{2\rho_2}\sum_{i=0}^{\infty} \rho_2^{-i}E_{t-1}z_{t+i} \\ E_{t-1}e_t &= \rho_1 e_{t-1} + \frac{1}{2(\rho_2-1)}\left[\delta\phi m_{t-1} - \phi x_{t-1} + \phi(1-\delta)\overline{y}_{t-1}\right] \ , \end{aligned} \tag{A12}$$

where the last equality comes from the definition of z and the assumption that the exogenous processes, i.e., money, demand, and income processes, follow random walks. Substituting the exchange rate forecast into (A5) gives, after much tedious rearrangement, the reduced form for the exchange rate. Reduced forms for the price level, real exchange rate, and output follow. See the next two pages. Exchange rate and output responses to money, demand, and income disturbances follow from substituting the random walk exogenous processes into the reduced forms and taking derivatives.

$$
\begin{aligned}
&[2(1-\rho_1)+\delta](1-\rho_1 L)e_t \\
&= \{\, [1-(1-\delta\phi)L] + \frac{\delta\phi}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \,\}\, m_t \\
&\quad - \{\, [1-L+\phi L] + \frac{\phi}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \,\}\, x_t \\
&\quad + \phi(1-\delta)\{\, L + \frac{1}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \,\}\, \overline{y}_t
\end{aligned}
$$

$$
\begin{aligned}
&[2(1-\rho_1)+\delta][1-(1-\delta\phi)L](1-\rho_1 L)p_t = \\
&\quad [\phi(1-\rho_1)+\delta\phi]\,\{\, [1-(1-\delta\phi)L] + (1-\rho_1)[2(1-L)+\phi L+\delta\phi L] \,\}\, m_{t-1} \\
&\qquad - [2(1-\rho_1)+\delta](1-\rho_1)\phi(1-\rho_1 L)\; m_{t-1} \\
&+ \; [\phi(1-\rho_1)+\delta\phi]\,\{\, \phi(1-\delta)L + \frac{(1-\rho_1)(1-\delta)}{\delta}[2(1-L)+\phi L+\delta\phi L] \,\}\, \overline{y}_{t-1} \\
&\qquad - [2(1-\rho_1)+\delta]\phi[1+\frac{(1-\delta)(1-\rho_1)}{\delta}](1-\rho_1 L)\; \overline{y}_{t-1}
\end{aligned}
$$

$$[2(1-\rho_1)+\delta](1-\rho_1 L)r_t =$$

$$\{ [1-(1-\delta\phi)L]+\frac{\delta\phi}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \} m_t$$

$$- \frac{\phi(1-\rho_1)+\delta\phi}{1-(1-\delta\phi)L}\{ [1-(1-\delta\phi)L]+(1-\rho_1)[2(1-L)+\phi L+\delta\phi L] \} m_{t-1}$$

$$+ [2(1-\rho_1)+\delta]\phi(1-\rho_1)\frac{1-\rho_1 L}{1-(1-\delta\phi)L} m_{t-1}$$

$$- \{ 1-L+\phi L+\frac{\phi}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \} x_t$$

$$+ \frac{\phi(1-\rho_1)+\delta\phi}{1-(1-\delta\phi)L}\{ 1-L+\phi L+\frac{1-\rho_1}{\delta}[2(1-L)+\phi L+\delta\phi L] \} x_{t-1}$$

$$- [2(1-\rho_1)+\delta]\phi[1+\frac{1-\rho_1}{\delta}]\frac{1-\rho_1 L}{1-(1-\delta\phi)L} x_{t-1}$$

$$+ \phi(1-\delta)\{ L+\frac{1}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \} \overline{y}_t$$

$$- \frac{\phi(1-\rho_1)+\delta\phi}{1-(1-\delta\phi)L}\{ \phi(1-\delta)L+\frac{(1-\rho_1)(1-\delta)}{\delta}[2(1-L)+\phi L+\delta\phi L] \} \overline{y}_{t-1}$$

$$+ [2(1-\rho_1)+\delta]\phi[1+\frac{(1-\delta)(1-\rho_1)}{\delta}]\frac{1-\rho_1 L}{1-(1-\delta\phi)L} \overline{y}_{t-1}$$

$$[2(1-\rho_1)+\delta][1-(1-\delta\phi)L](1-\rho_1 L)y_t =$$

$$(1-\rho_1+\delta)\{1-(1-\delta\phi)L+\frac{\delta\phi}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L]\}(1-L)m_t$$

$$- [2(1-\rho_1)+\delta]\frac{\delta\phi}{2(\rho_2-1)}(1-\rho_1 L)(1-L)m_t$$

$$+ (1-\rho_1+\delta)\phi(1-\delta)\{ L+\frac{1}{2(\rho_2-1)}[2(1-L)+\phi L+\delta\phi L] \}(1-l)\overline{y}_t$$

$$- [2(1-\rho_1)+\delta]\frac{\phi(1-\delta)}{2(\rho_2-1)}(1-\rho_1 L)(1-L)\overline{y}_t$$

$$+ [2(1-\rho_1)+\delta]\delta\phi(1-\rho_1 L)\overline{y}_{t-1}$$

APPENDIX B

BIVARIATE MODEL IDENTIFICATION

One can always in practice estimate the following VAR model for $X_t = [\Delta e_t, \Delta r_t]'$.

$$\begin{aligned} X_t &= A(L)X_{t-1} + \epsilon_t,\ var\{\epsilon_t\} = \Omega \\ &= A(1)X_{t-1} + \cdots + A(p)X_{t-p} + \epsilon_t \end{aligned} \tag{B.1}$$

If X_t is stationary then the VAR inverts to the VMA:

$$\begin{aligned} X_t &= B(L)\epsilon_t \\ &= \epsilon_t + B(1)\epsilon_{t-1} + \cdots, \end{aligned} \tag{B.2}$$

where $B(L) = [I-A(L)]^{-1}$. Fuller (1976, p.73) gives the formulas for the $B(s)$, $s\geq 0$. Given that the working model exists as a Wold representation,

$$\begin{aligned} X_t &= C(L)\eta_t,\ var\{\eta_t\} = I \\ &= C(0)\eta_t + C(1)\eta_{t-1} + \cdots, \end{aligned} \tag{B.3}$$

one can match coefficients across the working model and the VMA. Doing so, as in text, gives the long run and variance restrictions:

$$\begin{aligned} B_{21}(L{=}1)c_{11}(0) + B_{22}(L{=}1)c_{21}(0) &= 0 \\ c_{11}(0)^2 + c_{12}(0)^2 &= \omega_{11} \\ c_{11}c_{21} + c_{12}(0)c_{22}(0) &= \omega_{12} \\ c_{21}(0)^2 + c_{22}(0)^2 &= \omega_{22}. \end{aligned} \tag{B.4}$$

Solving the identifying equations gives $C(0)$ and $C(s) = B(s)C(0)$, $s\geq 1$. Thus the transformation matrix applicable to the VMA is $C(0)^{-1}$. I.e., transforming the shock vector in the VMA gives the working model: $X_t = B(L)\epsilon_t = B(L)C(0)C(0)^{-1}\epsilon_t = C(L)\eta_t$.

A final note concerns overidentifying the working model. Lee and Enders assumed a triangular $C(0)$, in particular that the contemporaneous effect of a nominal shock on the real rate is zero. This means that $c_{21}(0) = 0$ and hence that $B_{21}(L{=}1) = 0$ and $A_{21}(L{=}1) = 0$. In words, the last equality means that the cumulative effect of past nominal exchange rate changes on the change in the real rate is zero, a testable restriction on the VAR.

Blanchard and Quah (pp. 670-71) provide necessary and sufficient conditions under which bivariate results will not be misleading in the presence of multiple disturbances. Given that the Dornbusch model recognizes a monetary disturbance, a demand disturbance, and an income disturbance, focus upon the case of one nominal shock and two real shocks. Let X_t be generated by

$$X_t = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \end{bmatrix} \begin{bmatrix} \eta_{nt} \\ \eta_{r1t} \\ \eta_{r2t} \end{bmatrix},$$

where η_{nt}, η_{r1t}, and η_{r2t} respectively represent the one nominal and two real shocks. The nominal shock is restricted to have a temporary effect on the level of the real economic variable, say the real exchange rate, in the bottom of X_t. If a single real shock, η_{rt}, were intended to capture the effects of either real shock in a bivariate model, under what conditions would the bivariate results not be misleading?

The necessary and sufficient conditions are: i) $C_{12}(L) = \gamma_1 C_{22}(L)$ and ii) $C_{13}(L) = \gamma_2 C_{23}(L)$, where γ_1, γ_2 are scalars. Bivariate results for nominal and real rates are not misleading provided: i) the dynamic responses of the nominal rate to the first real shock are similar to the dynamic responses of the real rate to the first real shock, and ii) the dynamic responses of the nominal rate to the second real shock are similar to the dynamic responses of the real rate to the second real shock. Bivariate results cannot determine whether these conditions are met. However trivariate results can.

APPENDIX C

TRIVARIATE MODEL IDENTIFICATION

Matching coefficient matrices across VMA representations and summing over zero to infinity gives

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{bmatrix} = \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix}, \qquad \text{(C1)}$$

where C_{ij} denotes $C_{ij}(L=1)$, B_{ij} denotes $B_{ij}(L=1)$, and c_{ij} denotes $c_{ij}(0)$, $i,j = 1,2,3$. Matching coefficient matrices across VMA representations and taking the variance of each side gives

$$\begin{bmatrix} c_{11} & c_{12} & c_{13} \\ c_{21} & c_{22} & c_{23} \\ c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} c_{11} & c_{21} & c_{31} \\ c_{12} & c_{22} & c_{32} \\ c_{13} & c_{23} & c_{33} \end{bmatrix} = \begin{bmatrix} \omega_{11} & \omega_{12} & \omega_{13} \\ \omega_{21} & \omega_{22} & \omega_{23} \\ \omega_{31} & \omega_{32} & \omega_{33} \end{bmatrix}. \qquad \text{(C2)}$$

Forcing the nominal shock to have temporary effects on the levels of the real exchange rate and output and forcing the first real shock to have a temporary effect on the level of output implies $C_{21}(L=1) = C_{31}(L=1) = C_{32}(L=1) = 0$, and gives the following three identifying equations:

$$\begin{aligned} B_{21}c_{11} + B_{22}c_{21} + B_{23}c_{31} &= 0 \\ B_{31}c_{11} + B_{32}c_{21} + B_{33}c_{31} &= 0 \\ B_{31}c_{12} + B_{32}c_{22} + B_{33}c_{32} &= 0. \end{aligned} \qquad \text{(C3)}$$

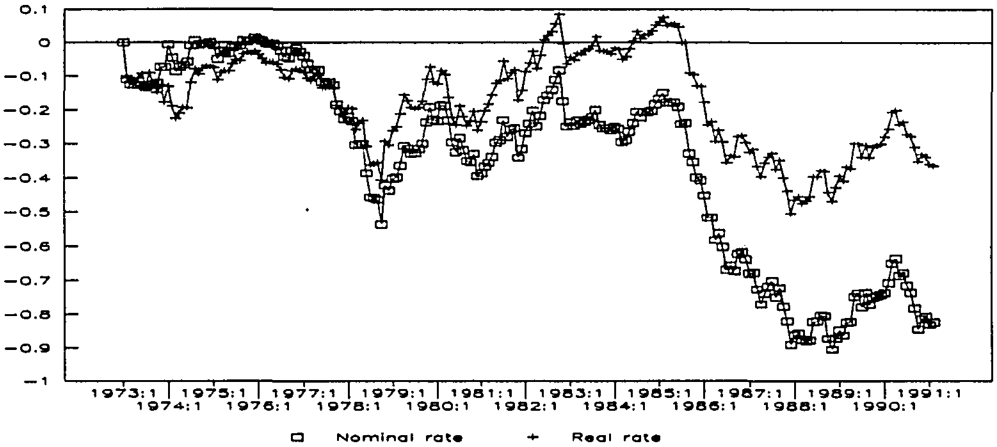
See the next page for the six variance restrictions.

Due to the nonlinearity of the system, hand-solving requires overidentifying C(0). Assuming C(0) upper triangular imposes the following restrictions on the VAR: $A_{21}(L=1) = A_{31}(L=1) = A_{32}(L=1) = 0$. As mentioned in the bivariate model identification, the reasonableness of overidentification will be tested as a statistical hypothesis. And imposing additional long run restrictions in place of the nonlinear variance restrictions fails to produce real solutions for C(0).

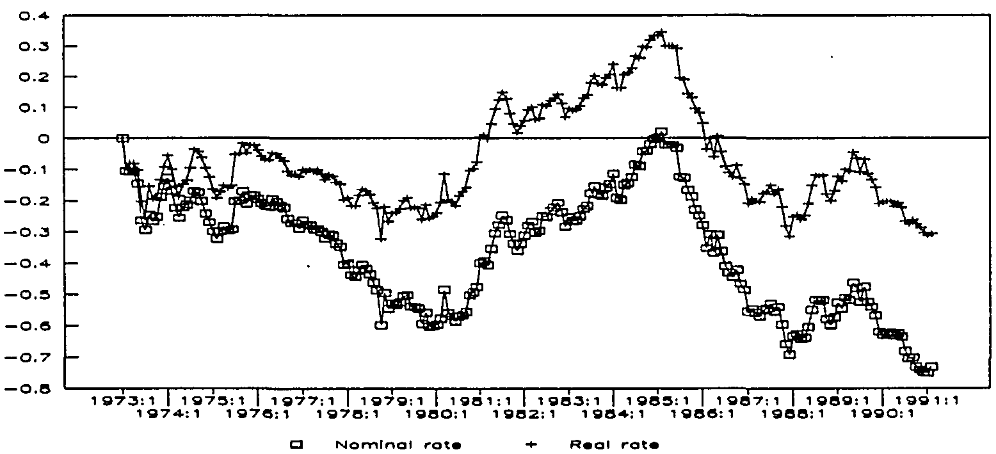
$$
\begin{aligned}
C_{11}^2 + C_{12}^2 + C_{13}^2 &= \omega_{11} \\
C_{11}C_{21} + C_{12}C_{22} + C_{13}C_{23} &= \omega_{12} \\
C_{11}C_{31} + C_{12}C_{32} + C_{13}C_{33} &= \omega_{13} \\
C_{21}^2 + C_{22}^2 + C_{23}^2 &= \omega_{22} \\
C_{21}C_{31} + C_{22}C_{32} + C_{23}C_{33} &= \omega_{23} \\
C_{31}^2 + C_{32}^2 + C_{33}^2 &= \omega_{33}.
\end{aligned}
\tag{C4}
$$

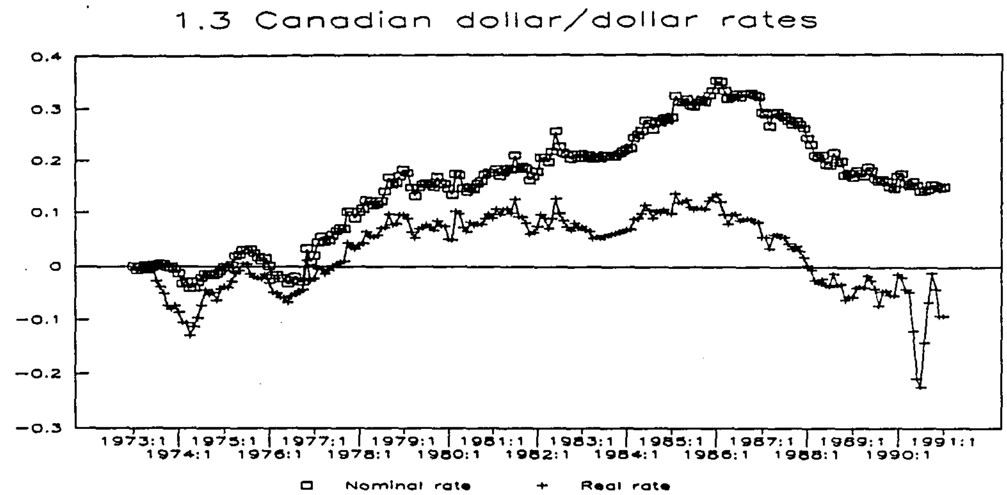
APPENDIX D
FIGURES

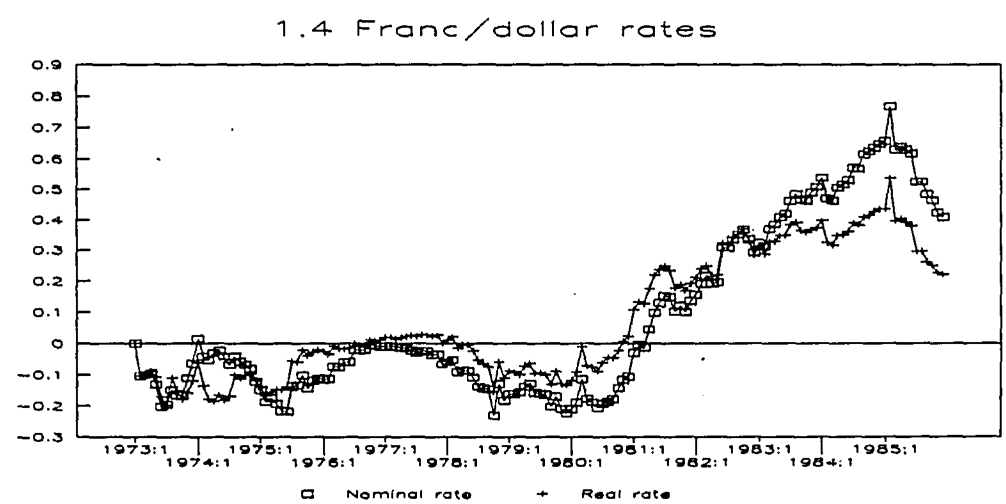
1.1 Yen/dollar rates



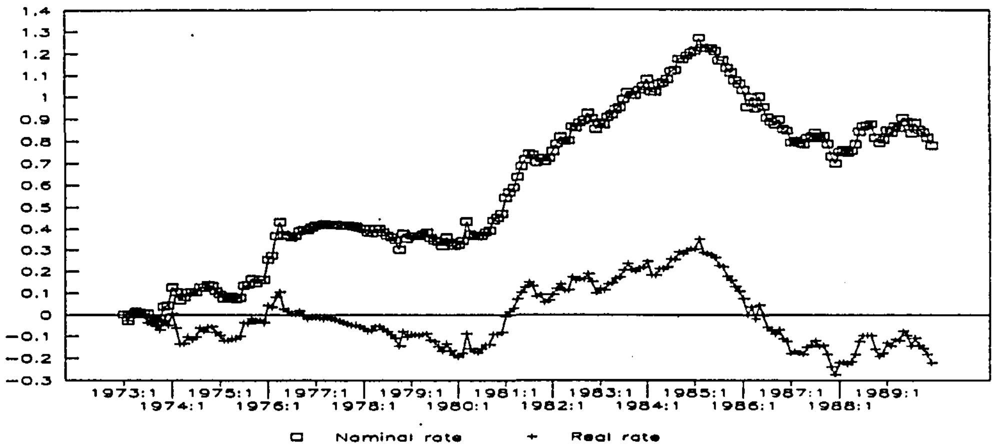
1.2 Mark/dollar rates



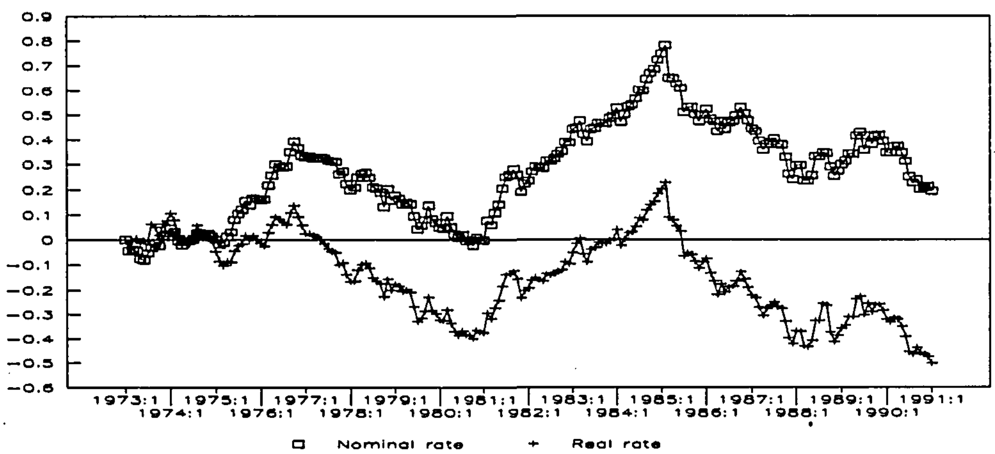

1.3 Canadian dollar/dollar rates
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
1973:1
1974:1
1975:1
1976:1
1977:1
1978:1
1979:1
1980:1
1981:1
1982:1
1983:1
1984:1
1985:1
1986:1
1987:1
1988:1
1989:1
1990:1
1991:1
Nominal rate
Real rate


1.4 Franc/dollar rates
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
1973:1
1974:1
1975:1
1976:1
1977:1
1978:1
1979:1
1980:1
1981:1
1982:1
1983:1
1984:1
1985:1
Nominal rate
Real rate

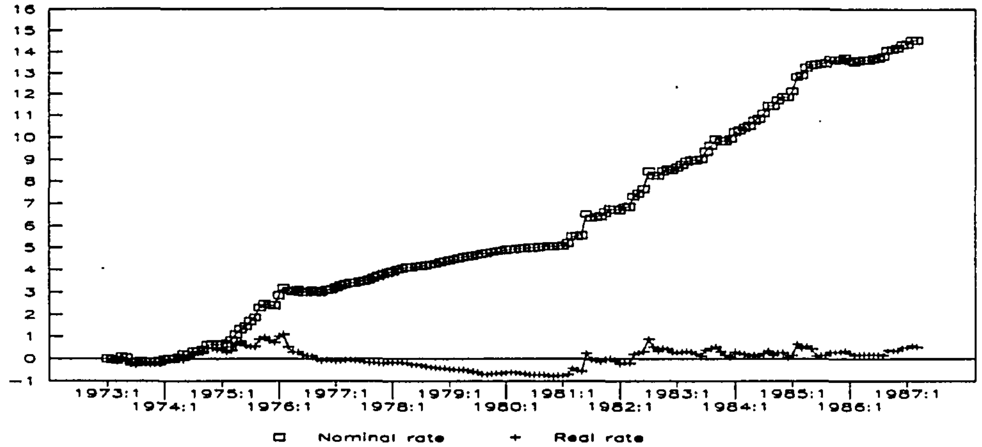
1.5 Lira/dollar rates



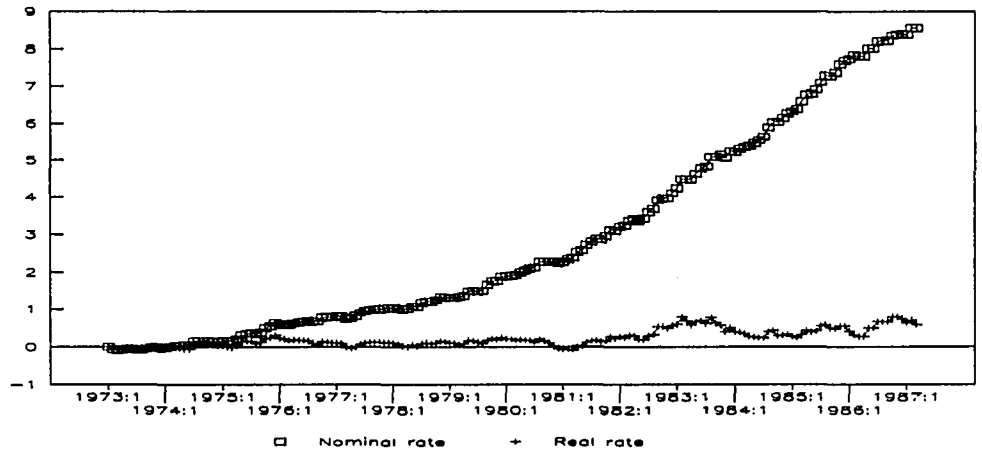
1.6 Pound/dollar rates



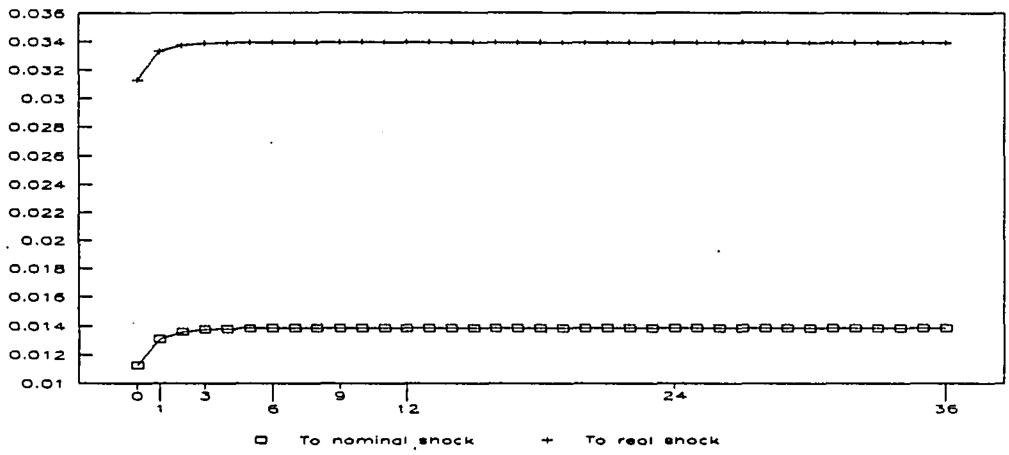
1.7 A.peso/dollar rates



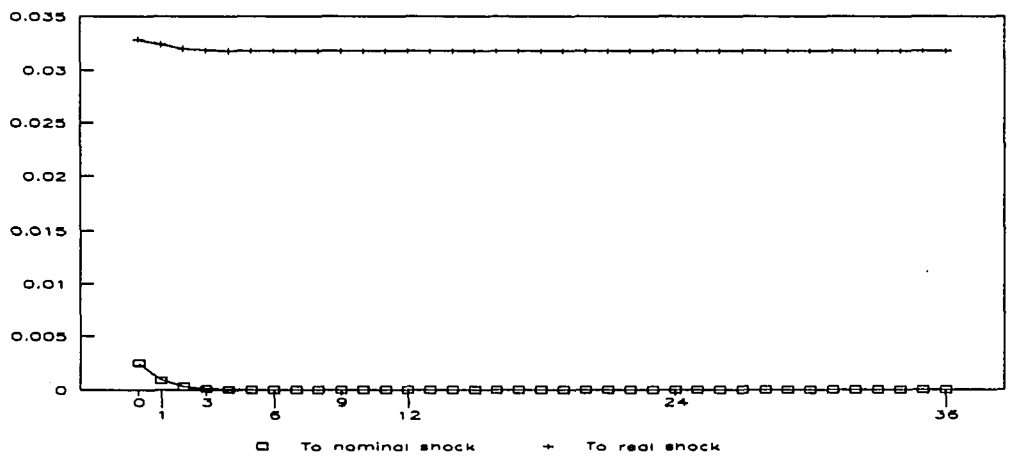
1.8 Cruzeiro/dollar rates



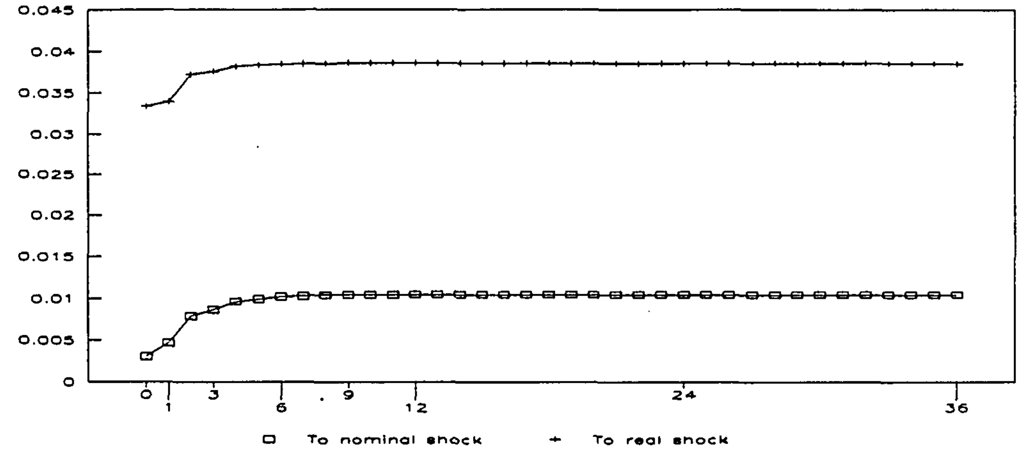
2.1A Nominal yen/dollar responses



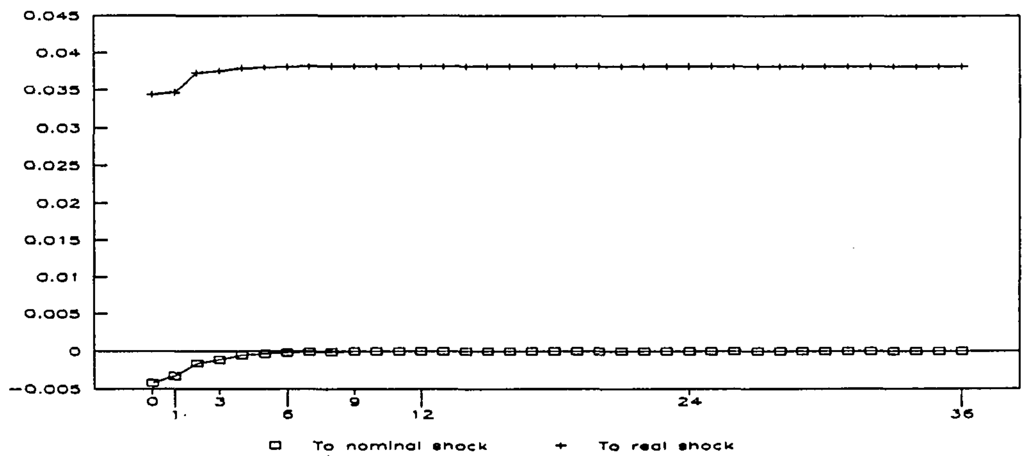
2.1B Real yen/dollar responses

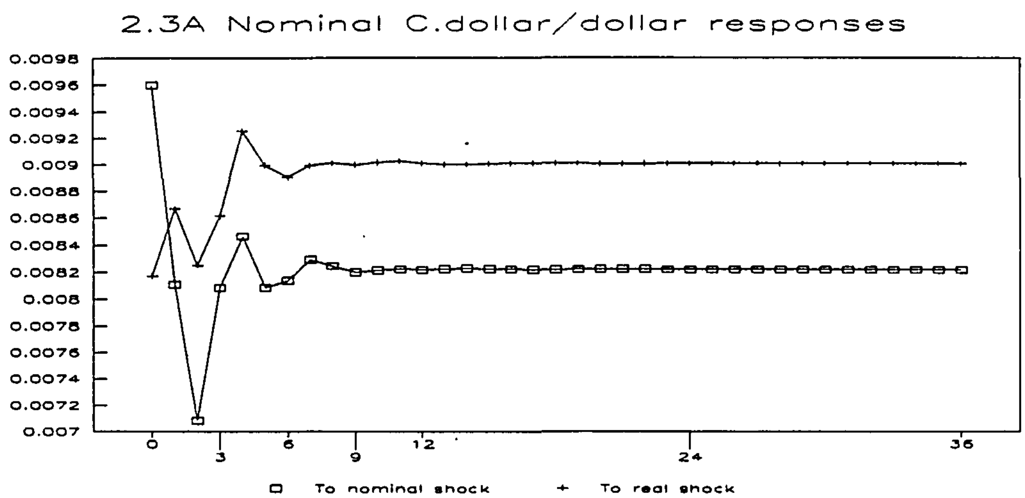


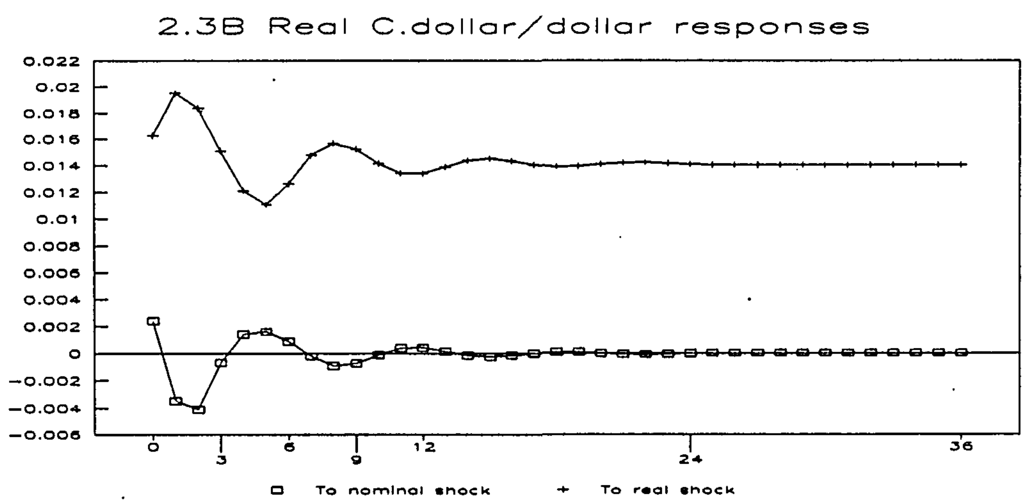
2.2A Nominal mark/dollar responses

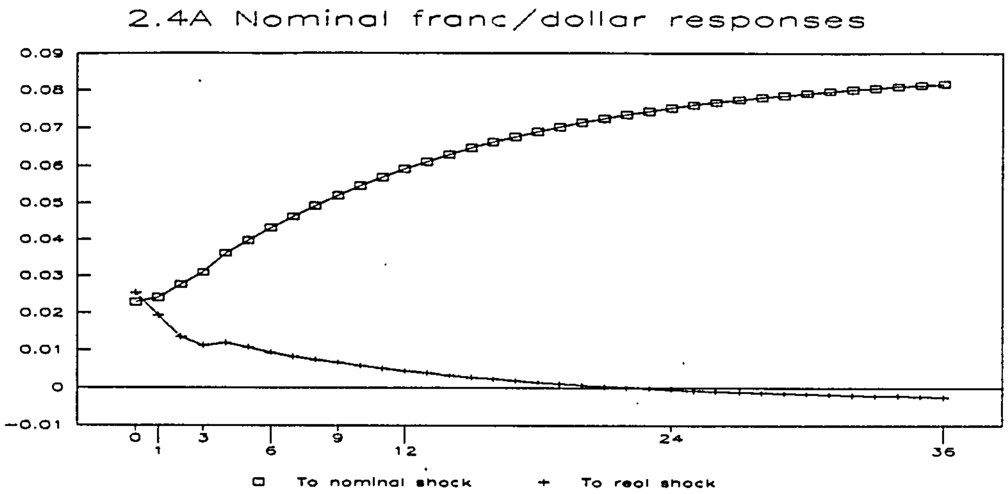


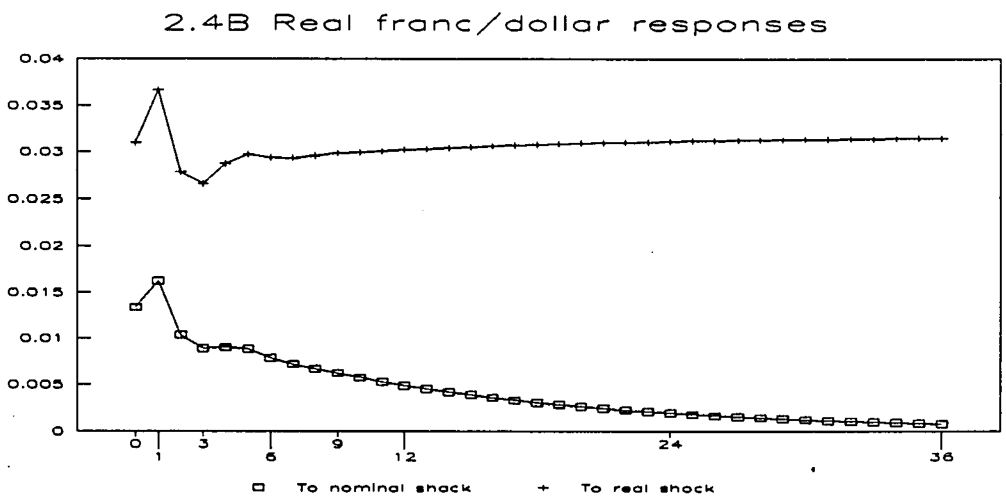
2.2B Real mark/dollar responses

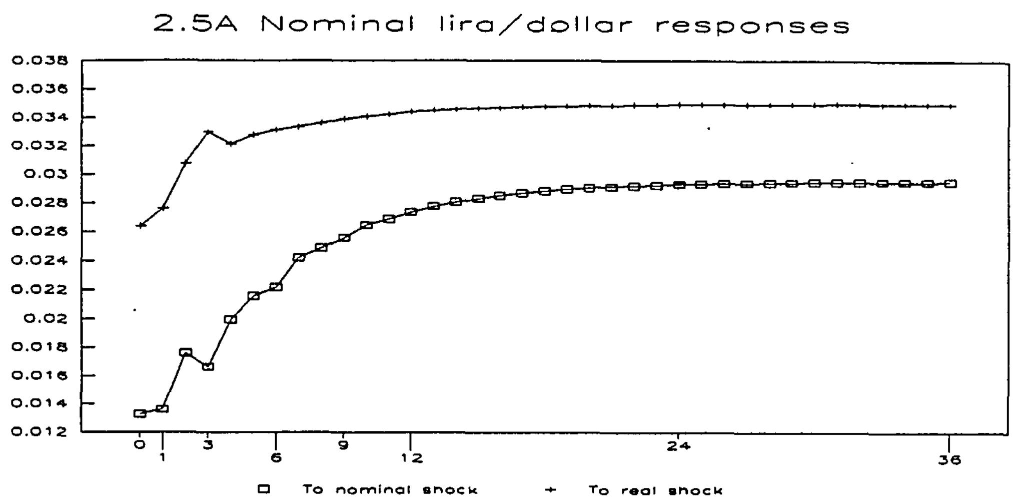


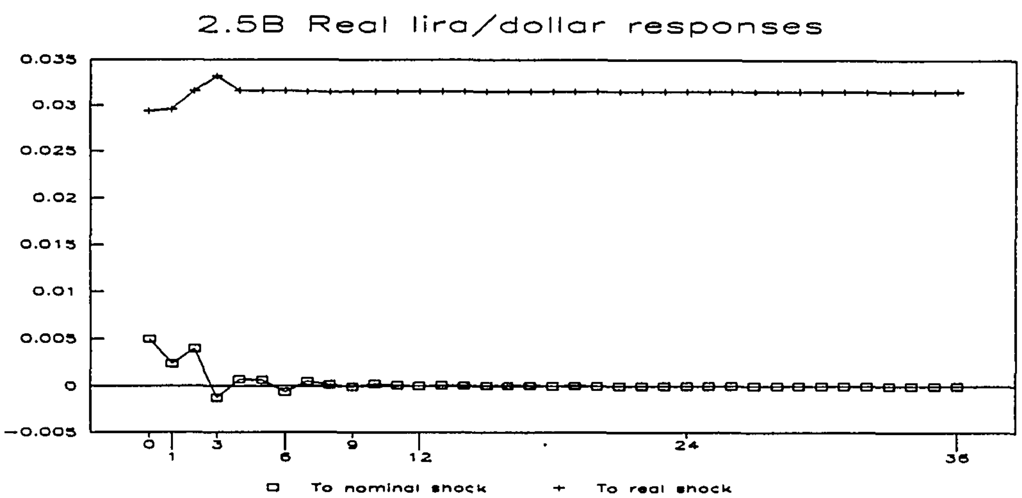

2.3A Nominal C.dollar/dollar responses
0.0098
0.0096
0.0094
0.0092
0.009
0.0088
0.0086
0.0084
0.0082
0.008
0.0078
0.0076
0.0074
0.0072
0.007
0
3
6
9
12
24
36
To nominal shock
To real shock


2.3B Real C.dollar/dollar responses
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
0
3
6
9
12
24
36
To nominal shock
To real shock

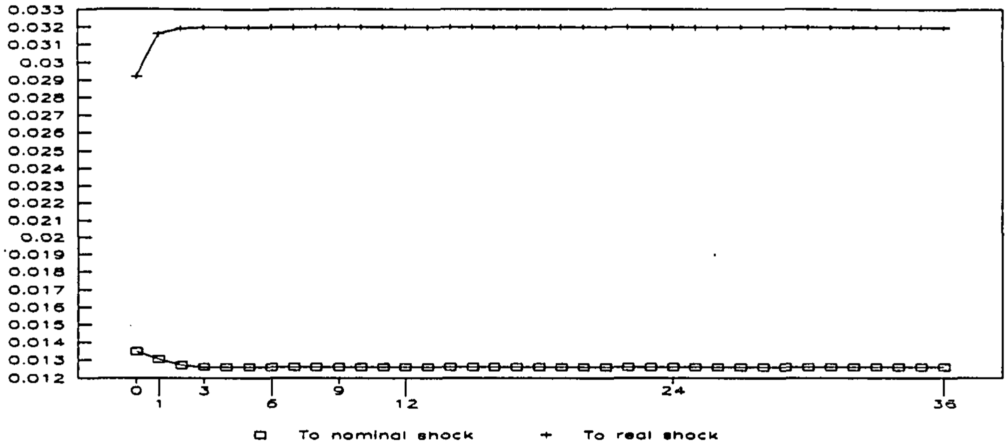

2.4A Nominal franc/dollar responses
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
0
1
3
6
9
12
24
36
To nominal shock
To real shock


2.4B Real franc/dollar responses
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
1
3
6
9
12
24
36
To nominal shock
To real shock

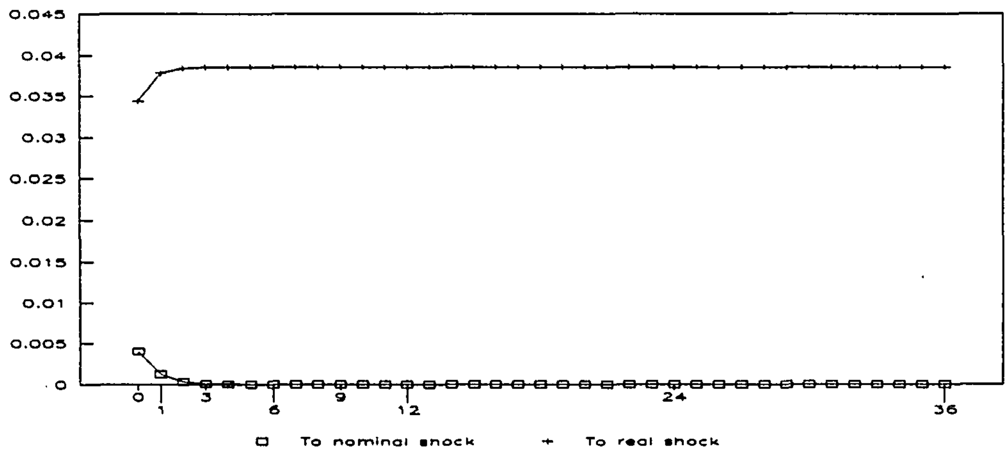

2.5A Nominal lira/dollar responses
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0
1
3
6
9
12
24
36
To nominal shock
To real shock


2.5B Real lira/dollar responses
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0
1
3
6
9
12
24
36
To nominal shock
To real shock

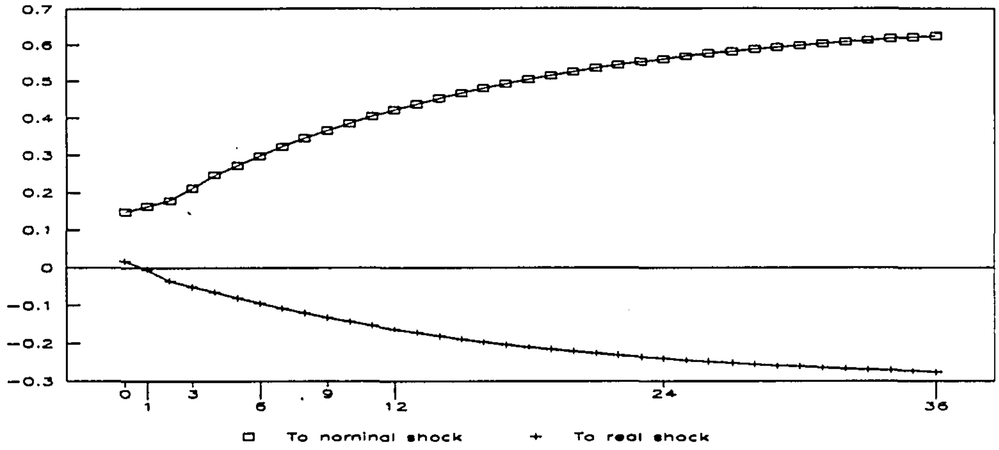
2.6A Nominal pound/dollar responses



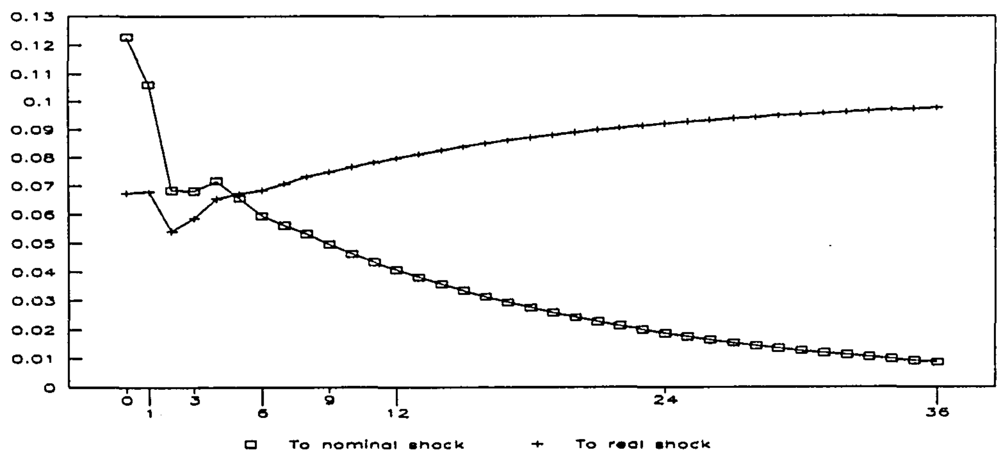
2.6B Real pound/dollar responses



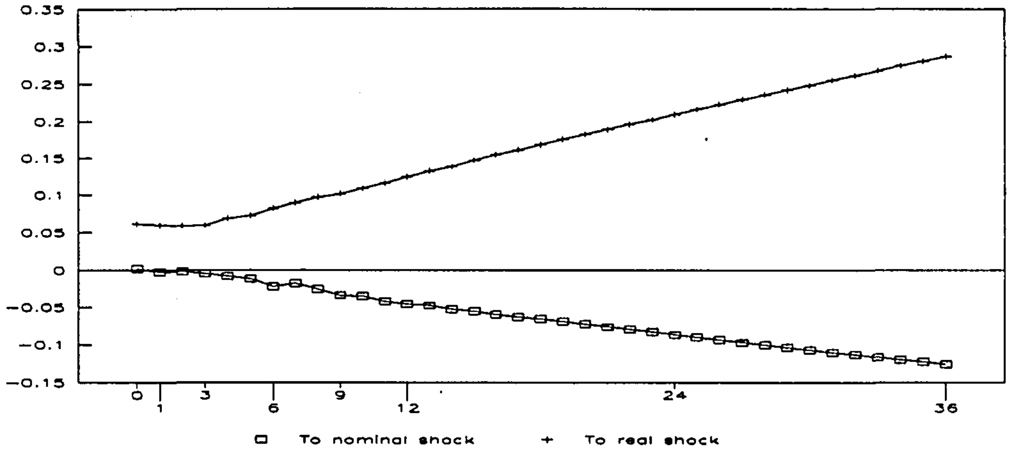
2.7A Nominal A.peso/dollar responses



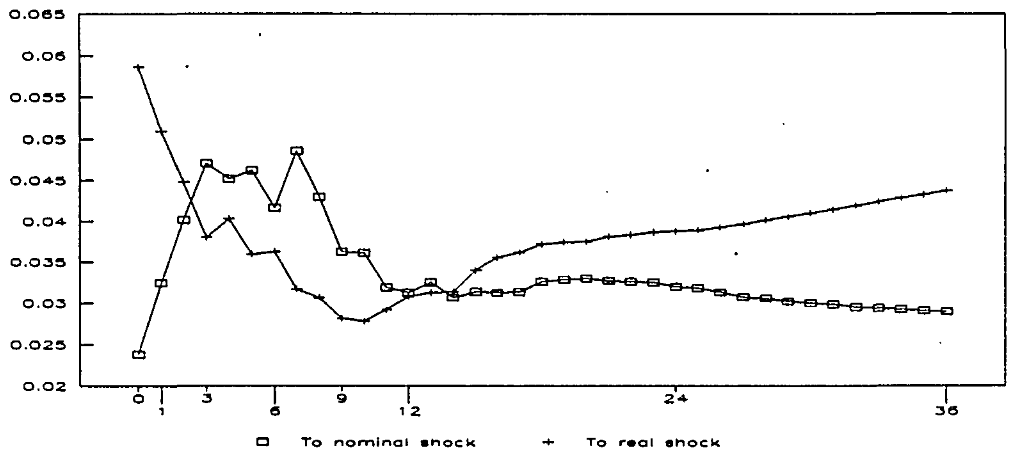
2.7B Real A.peso/dollar responses



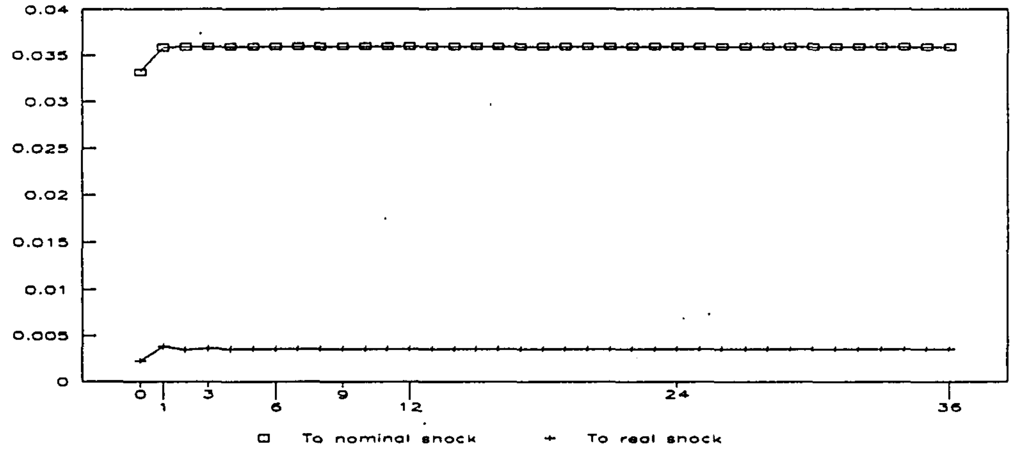
2.8A Nominal cruzeiro/dollar responses



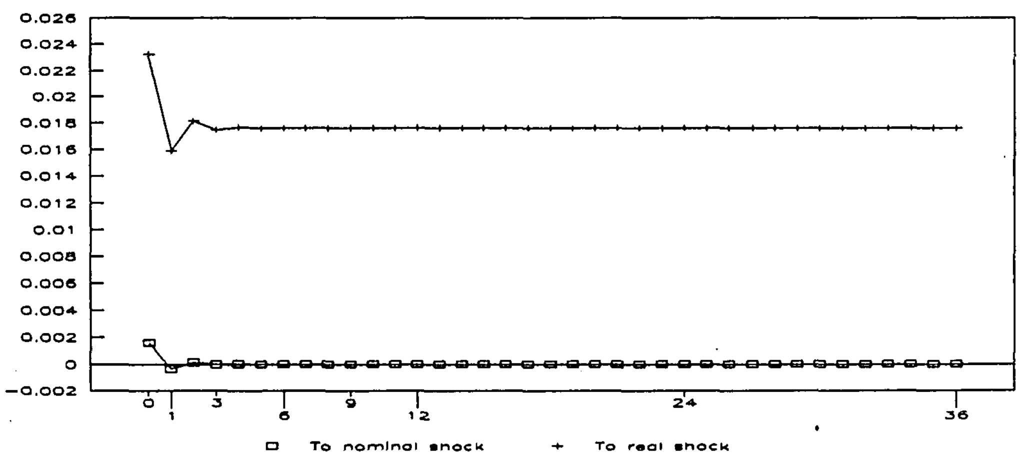
2.8B Real cruzeiro/dollar responses



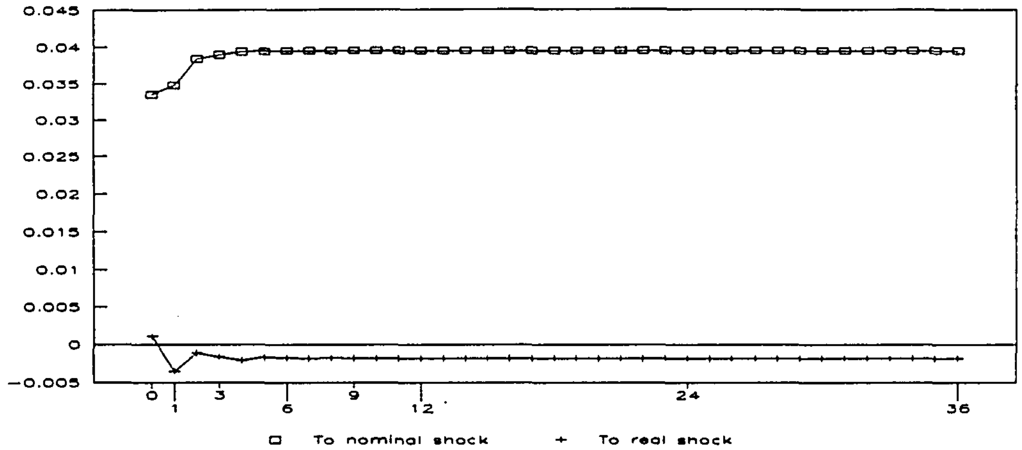
3.1A Nominal yen/dollar responses



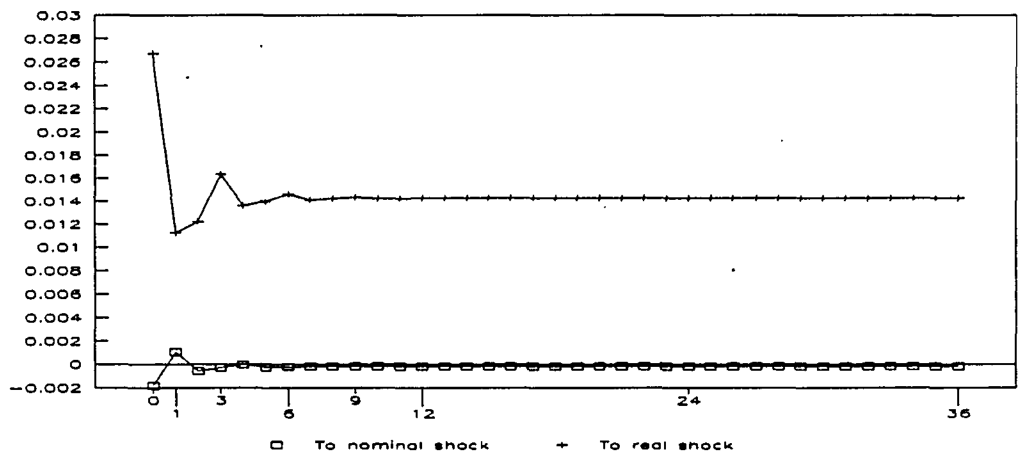
3.1B Japanese output responses

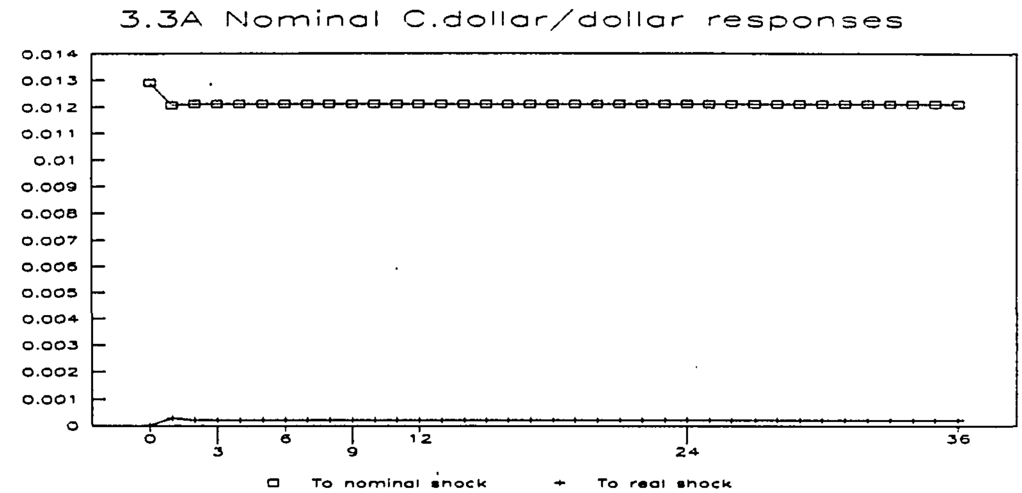


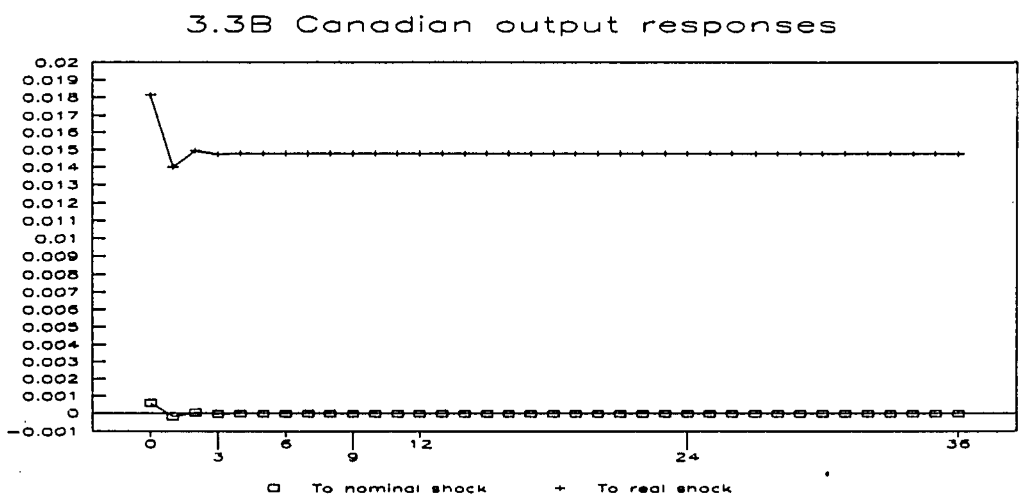
3.2A Nominal mark/dollar responses



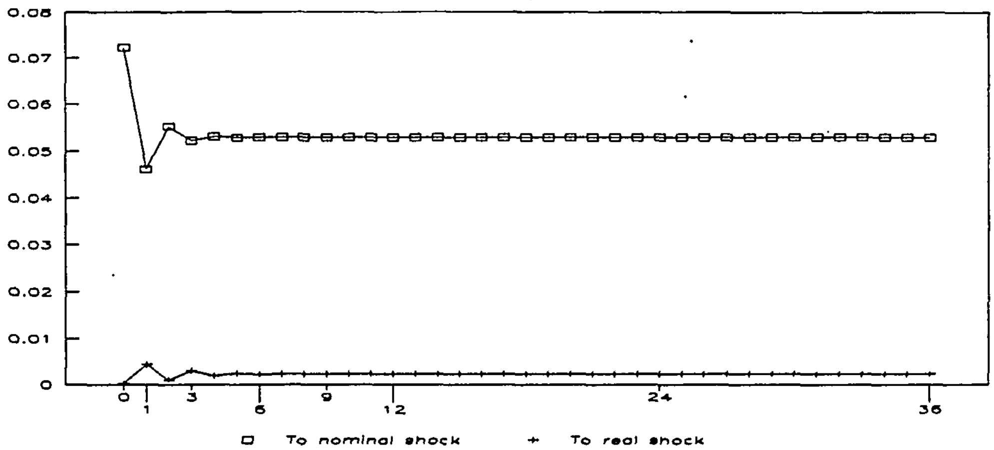
3.2B German output responses



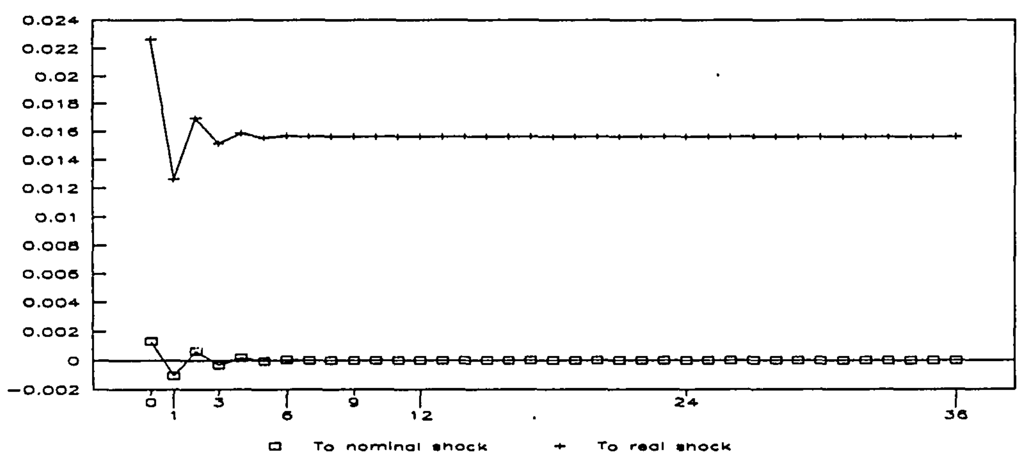

3.3A Nominal C.dollar/dollar responses
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
0
3
6
9
12
24
36
To nominal shock
To real shock

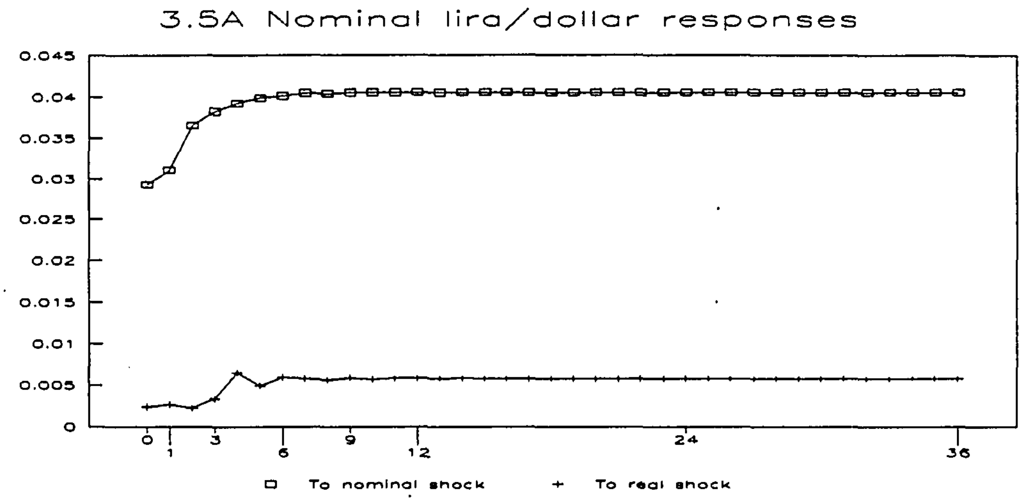

3.3B Canadian output responses
0.02
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
0
3
6
9
12
24
36
To nominal shock
To real shock

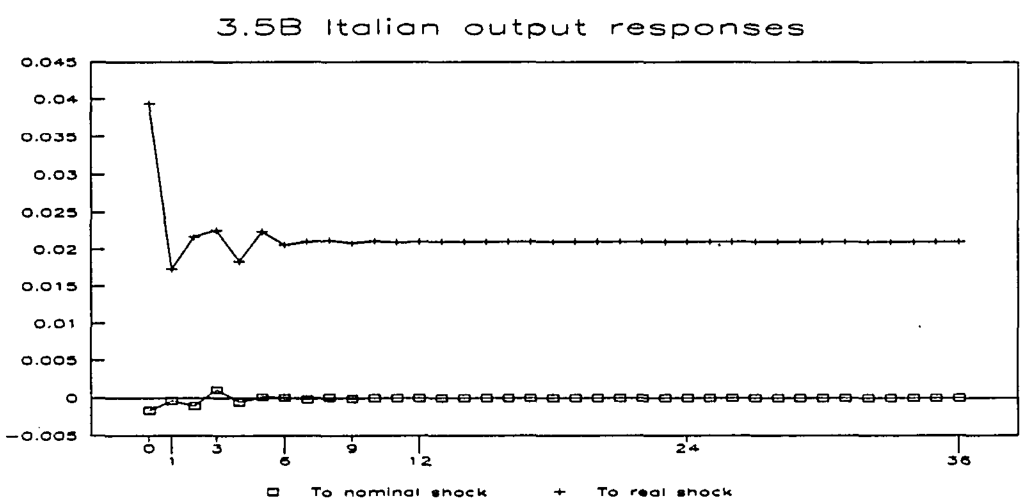
3.4A Nominal franc/dollar responses



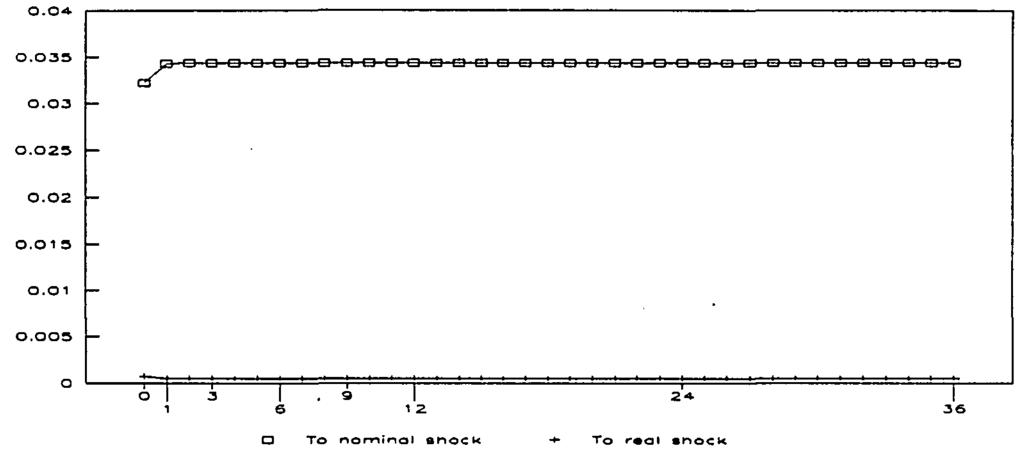
3.4B French output responses



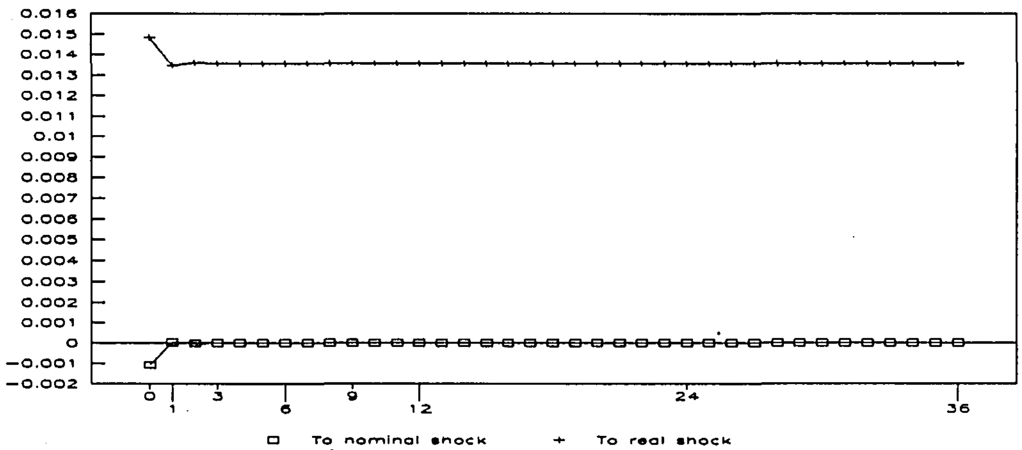

3.5A Nominal lira/dollar responses
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0 1 3 6 9 12 24 36
To nominal shock
To real shock


3.5B Italian output responses
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0 1 3 6 9 12 24 36
To nominal shock
To real shock

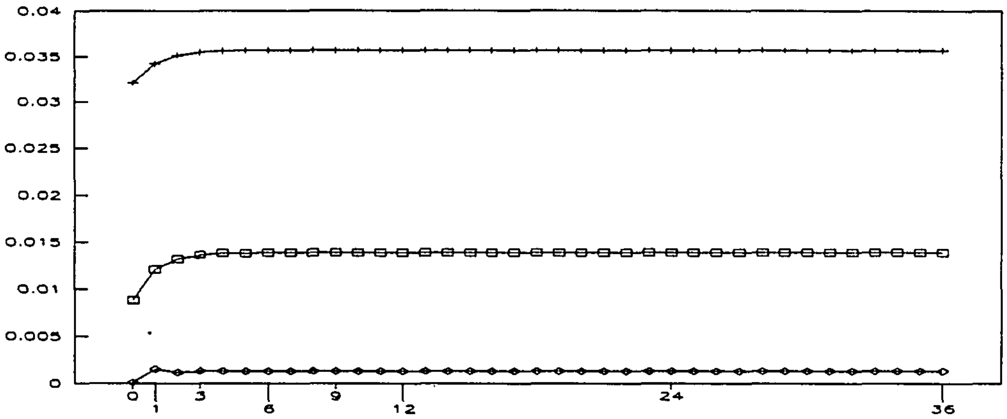
3.6A Nominal pound/dollar responses



3.6B U.K. output responses

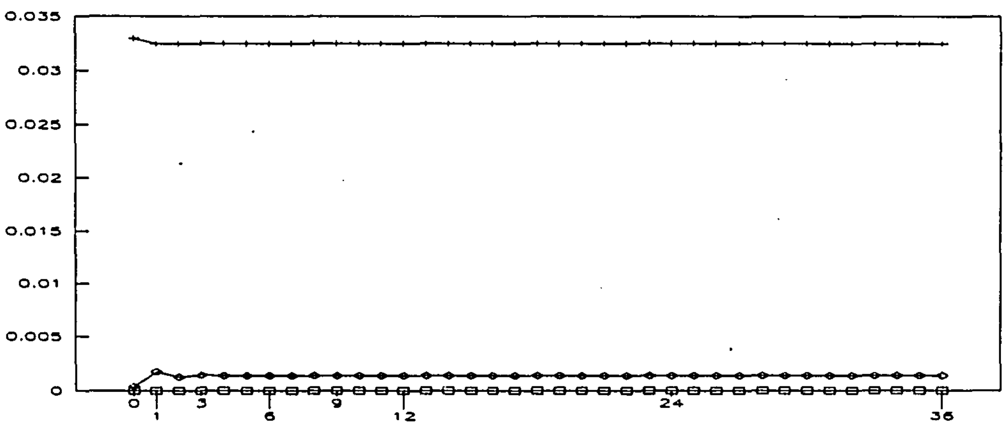


4.1A Nominal yen/dollar responses



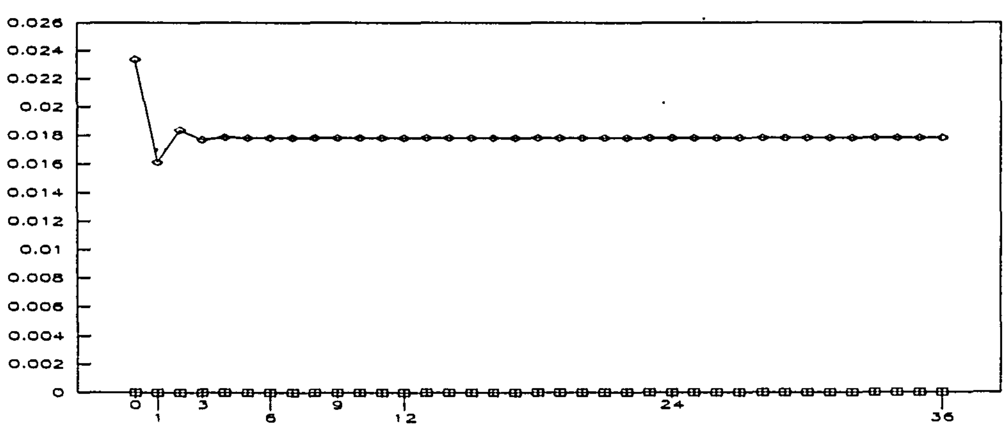
To nominal shock + To real shock 1 ◇ To real shock 2

4.1B Real yen/dollar responses

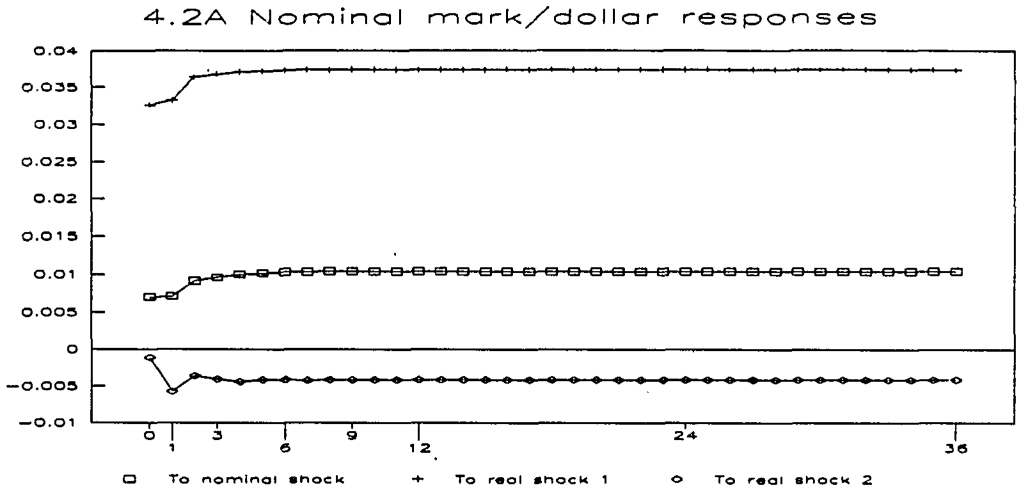


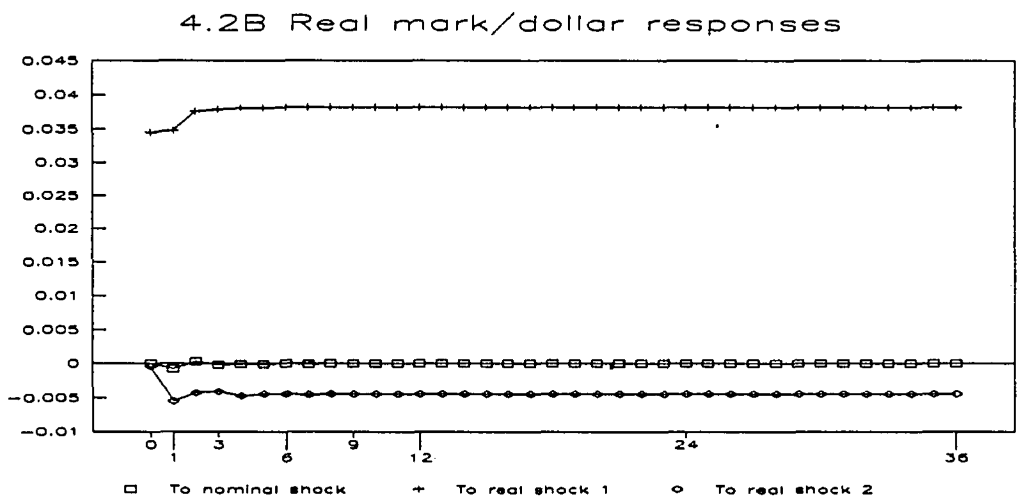
To nominal shock + To real shock 1 ◇ To real shock 2

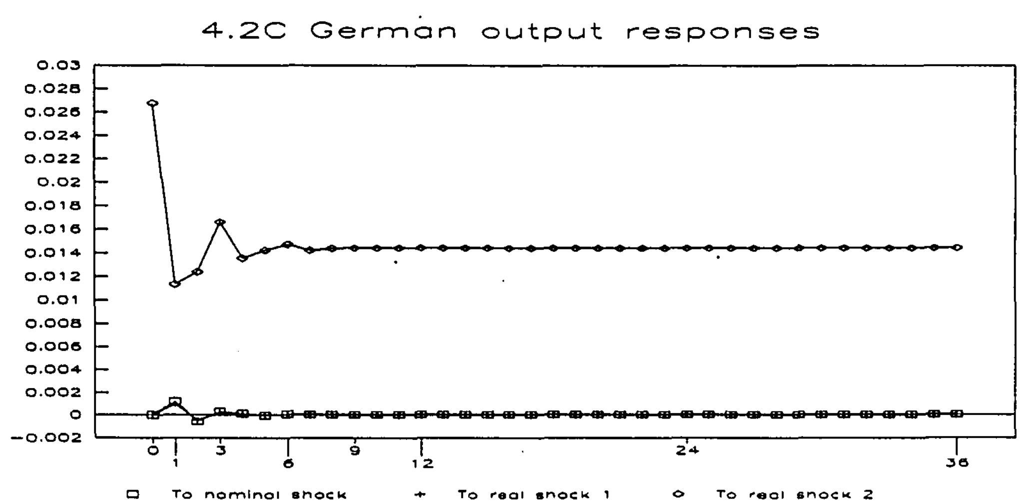
4.1C Japanese output responses



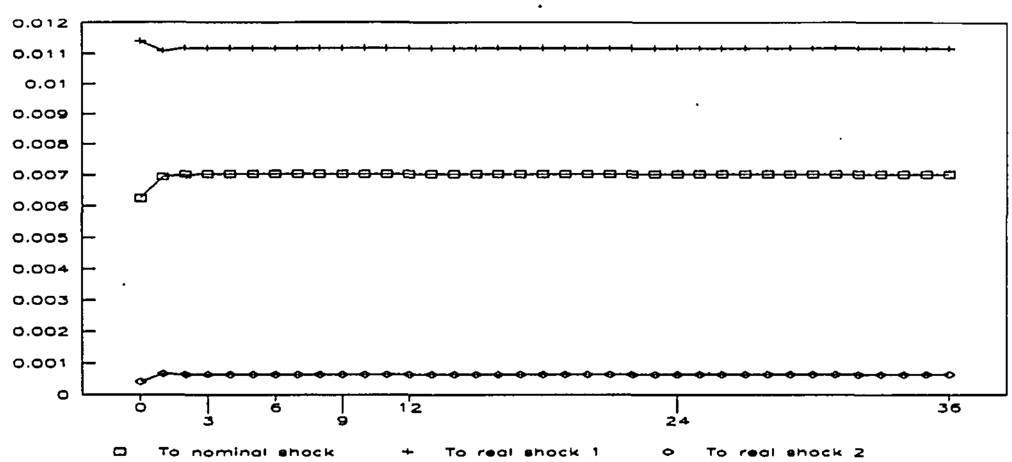
To nominal shock + To real shock 1 ◇ To real shock 2


4.2A Nominal mark/dollar responses
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
0
1
3
6
9
12
24
36
To nominal shock
To real shock 1
To real shock 2

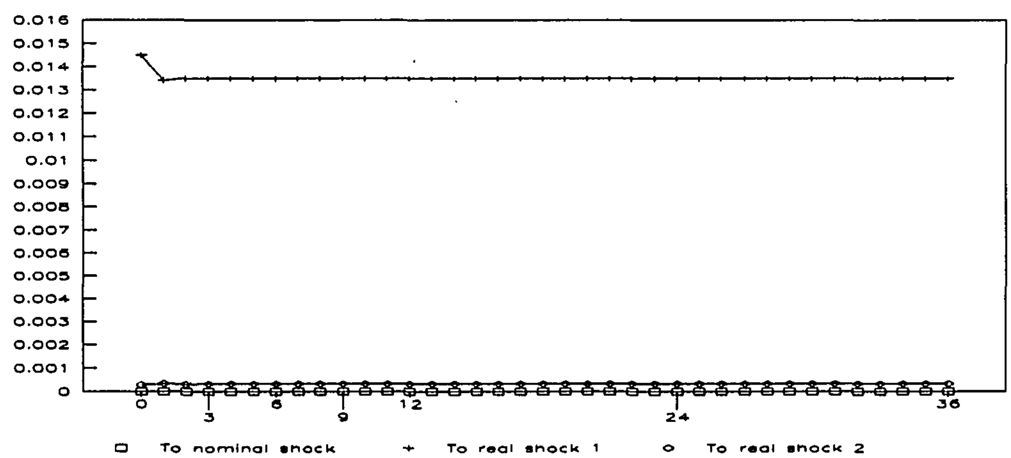

4.2B Real mark/dollar responses
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
0
1
3
6
9
12
24
36
To nominal shock
To real shock 1
To real shock 2


4.2C German output responses
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
0
1
3
6
9
12
24
36
To nominal shock
To real shock 1
To real shock 2

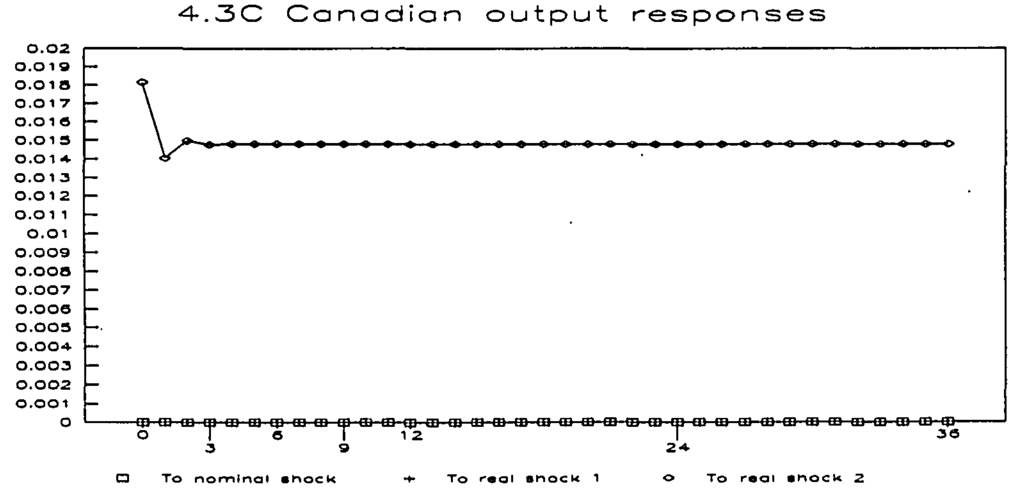
4.3A Nominal C.dollar/dollar responses



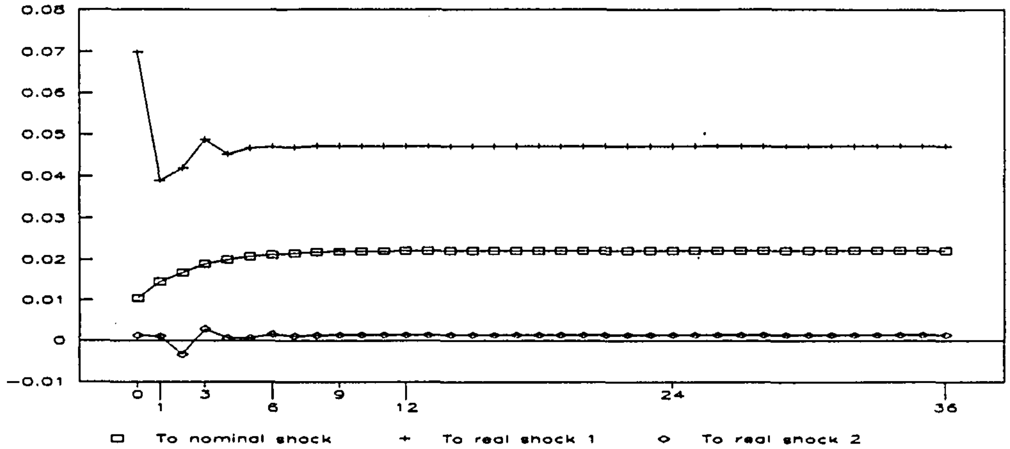
4.3B Real C.dollar/dollar responses



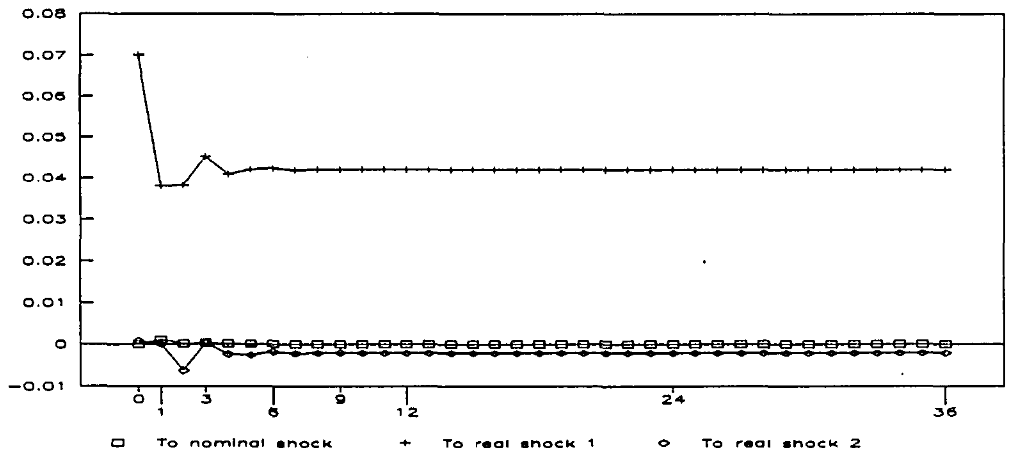
4.3C Canadian output responses



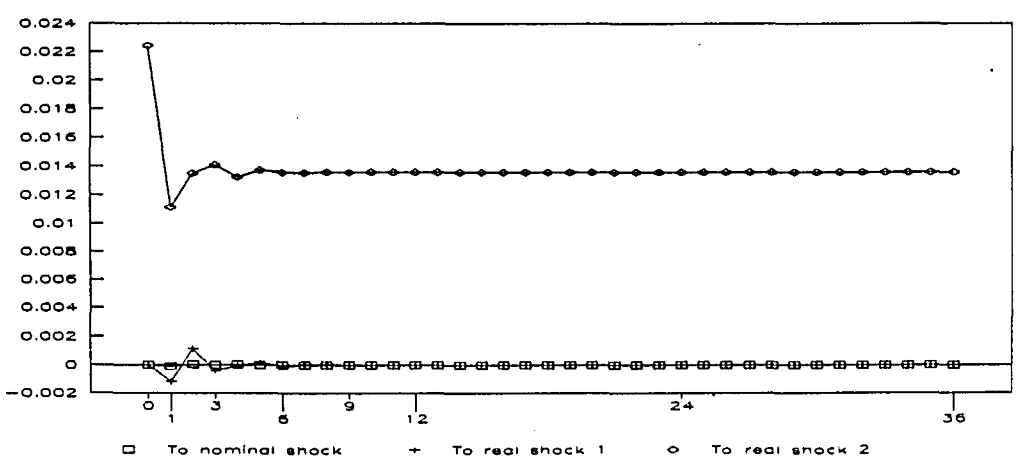
4.4A Nominal franc/dollar responses



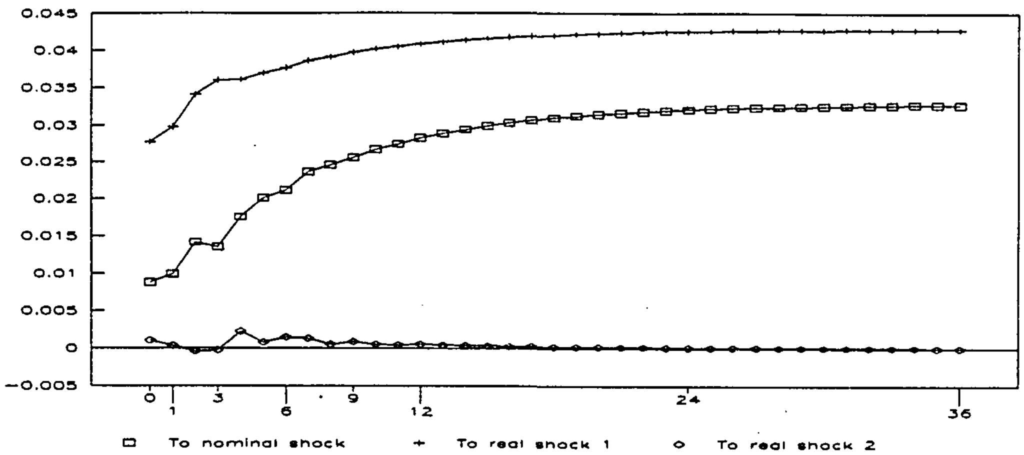
4.4B Real franc/dollar responses



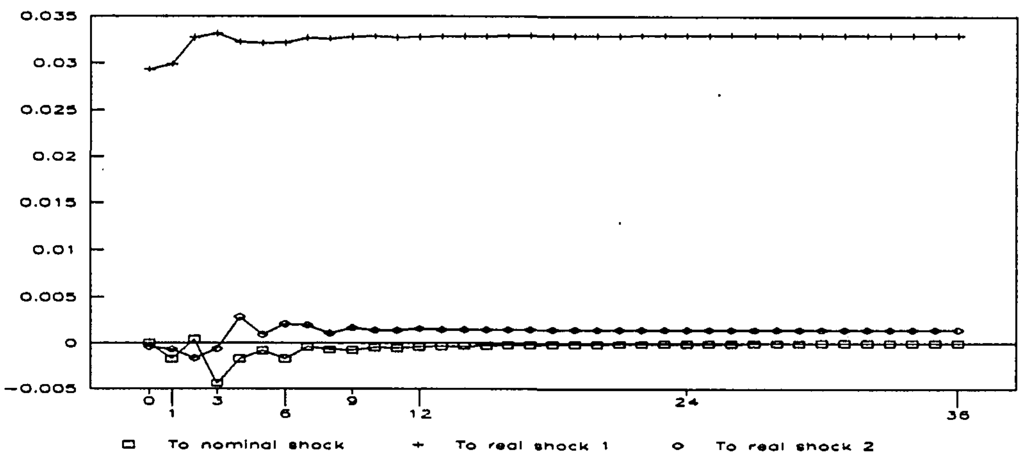
4.4C French output responses



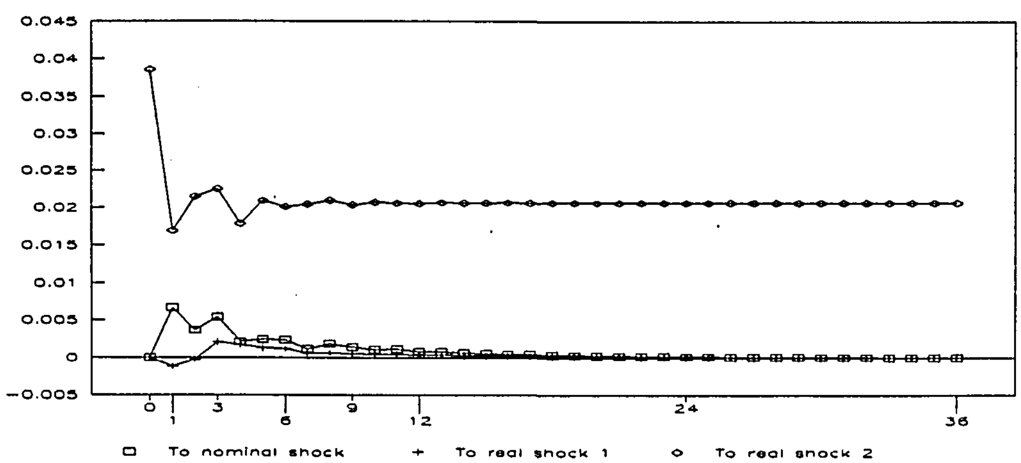
4.5A Nominal lira/dollar responses



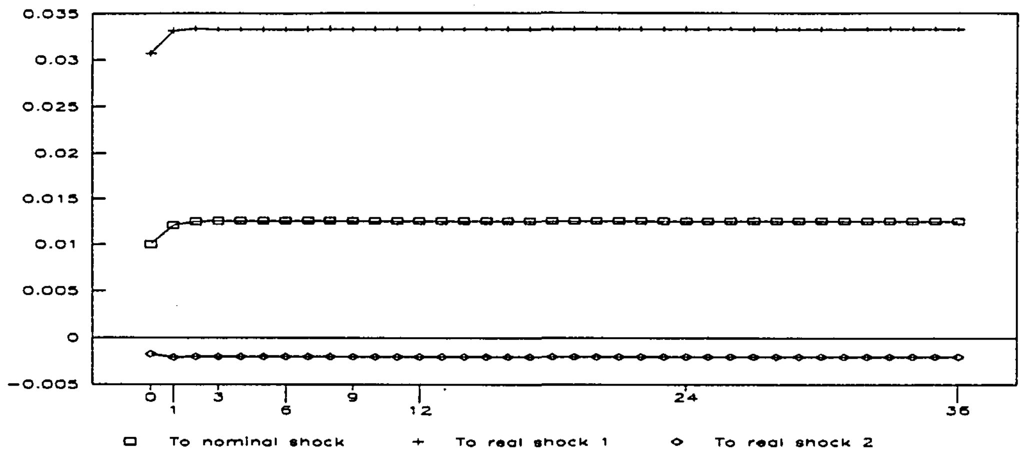
4.5B Real lira/dollar responses



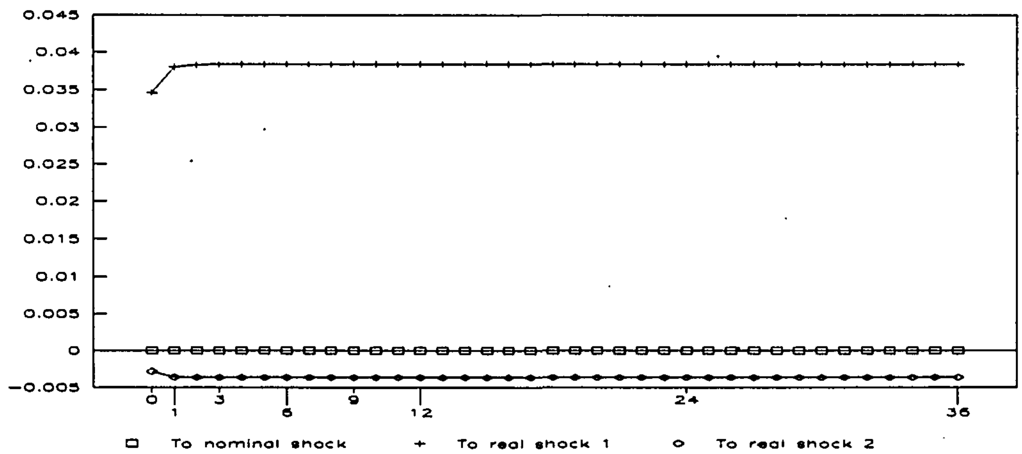
4.5C Italian output responses



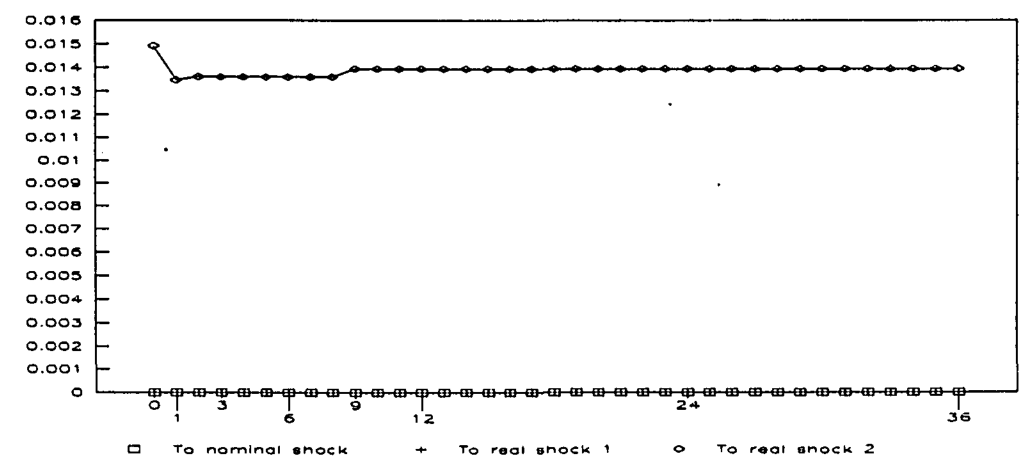
4.6A Nominal pound/dollar responses



4.6B Real pound/dollar responses



4.6C U.K. output responses



APPENDIX E
TABLES

Table 1 Lag length tests

	X_t	χ^2(df)	Sig.	H_0	H_1
Japan:	$[\Delta e_t,\Delta r_t]'$	5.56(4)	0.23	1	2
	$[\Delta e_t,\Delta y_t]'$	3.35(4)	0.50	1	2
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	9.48(9)	0.39	1	2
Germany:	$[\Delta e_t,\Delta r_t]'$	7.36(8)	0.50	2	4
	$[\Delta e_t,\Delta y_t]'$	4.06(8)	0.85	2	4
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	19.06(18)	0.39	2	4
Canada:	$[\Delta e_t,\Delta r_t]'$	6.96(12)	0.86	4	6
	$[\Delta e_t,\Delta y_t]'$	2.72(4)	0.61	1	3
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	3.90(9)	0.92	1	2
France:	$[\Delta e_t,\Delta r_t]'$	11.86(8)	0.16	2	4
	$[\Delta e_t,\Delta y_t]'$	7.60(4)	0.11	1	2
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	25.94(18)	0.10	2	4
Italy:	$[\Delta e_t,\Delta r_t]'$	6.41(12)	0.89	4	6
	$[\Delta e_t,\Delta y_t]'$	5.11(8)	0.75	2	4
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	18.37(27)	0.89	4	6
U.K.:	$[\Delta e_t,\Delta r_t]'$	8.92(4)	0.06	1	2
	$[\Delta e_t,\Delta y_t]'$	0.95(4)	0.92	1	2
	$[\Delta e_t,\Delta r_t,\Delta y_t]'$	11.31(9)	0.26	1	2
Argentina:	$[\Delta e_t,\Delta r_t]'$	10.37(8)	0.24	2	4
Brazil:	$[\Delta e_t,\Delta r_t]'$	11.15(8)	0.19	8	10

Note: χ^2(df) = computed value of the chi-square test statistic with df degees of freedom; Sig. = significance level of the test, i.e., the probability of a chi-square value greater than the computed value under the null; H_0: VAR lag length under the null; H_1: VAR lag length under the alternative.

The tests were conducted successively: H_0: VAR(1) vs. H_1: VAR(2), H_0: VAR(2) vs. H_1: VAR(4), and so on until the null was rejected at the 5% level. Thus the number of lag lengths reported under H_0 indicates the selected lag length for the VAR.

Table 2.1 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Japan			
e	1	11.46	88.54
	3	11.70	88.30
	6	11.70	88.30
	9	11.70	88.30
	12	11.70	88.30
	24	11.70	88.30
	36	11.70	88.30
r	1	0.58	99.42
	3	0.85	99.15
	6	0.85	99.15
	9	0.85	99.15
	12	0.85	99.15
	24	0.85	99.15
	36	0.85	99.15

Table 2.2 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in		Horizon	Shock η_{nt}	Shock η_{rt}
Germany				
	e	1	0.82	99.18
		3	1.92	98.08
		6	2.07	97.93
		9	2.08	97.92
		12	2.08	97.92
		24	2.08	97.92
		36	2.08	97.92
	r	1	1.50	98.50
		3	1.80	98.20
		6	1.85	98.15
		9	1.85	98.15
		12	0.85	99.15
		24	0.85	99.15
		36	0.85	99.15

Table 2.3 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Canada			
e	1	57.98	42.02
	3	58.67	41.33
	6	58.77	41.23
	9	58.77	41.23
	12	58.77	41.23
	24	58.77	41.23
	36	58.77	41.23
r	1	2.13	97.87
	3	12.94	87.06
	6	16.16	83.84
	9	16.32	83.68
	12	16.39	83.61
	24	16.41	83.59
	36	16.41	83.59

Table 2.4 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	Shock η_{rt}
France			
e	1	44.94	55.06
	3	43.06	56.94
	6	45.09	54.91
	9	46.22	53.78
	12	46.91	53.09
	24	47.87	52.13
	36	48.01	51.99
r	1	15.67	84.33
	3	17.15	82.85
	6	17.20	82.80
	9	17.30	82.70
	12	17.33	82.67
	24	17.39	82.61
	36	17.40	82.60

Table 2.5 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Italy			
e	1	20.17	79.83
	3	21.35	78.65
	6	22.48	77.52
	9	22.88	77.12
	12	23.00	77.00
	24	23.05	76.95
	36	23.05	76.95
r	1	2.77	97.23
	3	3.73	96.27
	6	6.90	93.10
	9	7.17	92.83
	12	7.18	92.82
	24	7.18	92.82
	36	7.18	92.82

Table 2.6 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

	Forecast error in	Horizon	Shock η_{nt}	η_{rt}
U.K.				
	e	1	17.60	82.40
		3	17.53	82.47
		6	17.53	82.47
		9	17.53	82.47
		12	17.53	82.47
		24	17.53	82.47
		36	17.53	82.47
	r	1	1.35	98.65
		3	2.03	97.97
		6	2.04	97.96
		9	2.04	97.96
		12	2.04	97.96
		24	2.04	97.96
		36	2.04	97.96

Table 2.7 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Argentina			
e	1	98.83	1.17
	3	93.15	6.85
	6	91.68	8.32
	9	90.49	9.51
	12	89.79	10.21
	24	88.81	11.19
	36	88.62	11.38
r	1	76.74	23.26
	3	77.90	22.10
	6	77.70	22.30
	9	77.72	22.28
	12	77.72	22.28
	24	77.72	22.28
	36	77.71	22.29

Table 2.8 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Brazil			
e	1	0.07	99.93
	3	0.61	99.39
	6	1.42	98.58
	9	5.84	94.16
	12	8.00	92.00
	24	9.55	90.45
	36	10.80	89.20
r	1	14.16	85.84
	3	16.55	83.45
	6	17.28	82.72
	9	19.05	80.95
	12	20.14	79.86
	24	20.21	79.79
	36	20.22	79.78

Table 3.1 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta y_t]'$$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Japan			
e	1	99.55	0.45
	3	99.33	0.67
	6	99.33	0.67
	9	99.33	0.67
	12	99.33	0.67
	24	99.33	0.67
	36	99.33	0.67
y	1	0.47	99.53
	3	1.11	98.89
	6	1.11	98.89
	9	1.11	98.89
	12	1.11	98.89
	24	1.11	98.89
	36	1.11	98.89

Table 3.2 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta y_t]'$$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Germany			
e	1	99.89	0.11
	3	97.58	2.42
	6	97.53	2.47
	9	97.53	2.47
	12	97.53	2.47
	24	97.53	2.47
	36	97.53	2.47
y	1	0.48	99.52
	3	1.47	98.53
	6	1.46	98.54
	9	1.46	98.54
	12	1.46	98.54
	24	1.46	98.54
	36	1.46	98.54

Table 3.3 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta y_t]'$

Forecast error in		Horizon	Shock η_{nt}	η_{rt}
Canada				
	e	1	100.00	0.00
		3	99.95	0.05
		6	99.95	0.05
		9	99.95	0.05
		12	99.95	0.05
		24	99.95	0.05
		36	99.95	0.05
	y	1	0.12	99.88
		3	0.31	99.69
		6	0.31	99.69
		9	0.31	99.69
		12	0.31	99.69
		24	0.31	99.69
		36	0.31	99.69

Table 3.4 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta y_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
France			
e	1	100.00	0.00
	3	99.51	0.49
	6	99.41	0.59
	9	99.41	0.59
	12	99.41	0.59
	24	99.41	0.59
	36	99.41	0.59
y	1	0.33	99.67
	3	1.55	98.45
	6	1.73	98.27
	9	1.73	98.27
	12	1.73	98.27
	24	1.73	98.27
	36	1.73	98.27

Table 3.5 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta y_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{rt}
Italy			
e	1	99.33	0.67
	3	99.33	0.67
	6	97.90	2.10
	9	97.78	2.22
	12	97.77	2.23
	24	97.77	2.23
	36	97.77	2.23
y	1	0.17	99.83
	3	0.23	99.77
	6	0.58	99.42
	9	0.59	99.41
	12	0.59	99.41
	24	0.59	99.41
	36	0.59	99.41

Table 3.6 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta y_t]'$

	Forecast error in	Horizon	Shock η_{nt}	η_{rt}
U.K.				
	e	1	99.95	0.05
		3	99.95	0.05
		6	97.95	0.05
		9	97.95	0.05
		12	97.95	0.05
		24	97.95	0.05
		36	97.95	0.05
	y	1	0.53	99.47
		3	1.07	98.93
		6	1.07	98.93
		9	1.07	98.93
		12	1.07	98.93
		24	1.07	98.93
		36	1.07	98.93

Table 4 Overidentification restriction tests

	X_t	χ^2(df)	Sig.
Japan:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	1.51(3)	0.68
Germany:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	2.50(3)	0.47
Canada:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	6.04(3)	0.11
France:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	9.27(3)	0.03
Italy:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	4.73(3)	0.89
U.K.:	$[\Delta e_t, \Delta r_t, \Delta y_t]'$	2.68(3)	0.44

Note: χ^2 (df) = computed value of the chi-square test statistic with df degees of freedom under the null $A_{21}(L=1) = A_{31}(L=1) = A_{32}(L=1) = 0$. Sig. = significance level of the test, i.e., the probability of a chi-square value greater than the computed value under the null.

Table 5.1 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$$

Forecast error in	Horizon	Shock η_{nt}	η_{r1t}	η_{r2t}
Japan				
e	1	7.06	92.94	0.00
	3	7.97	91.83	0.19
	6	7.99	91.82	0.20
	9	7.99	91.82	0.20
	12	7.99	91.82	0.20
	24	7.99	91.82	0.20
	36	7.99	91.82	0.20
r	1	0.00	99.99	0.01
	3	0.00	99.80	0.20
	6	0.00	99.80	0.20
	9	0.00	99.80	0.20
	12	0.00	99.80	0.20
	24	0.00	99.80	0.20
	36	0.00	99.80	0.20
y	1	0.00	0.00	100.00
	3	0.00	0.00	100.00
	6	0.00	0.00	100.00
	9	0.00	0.00	100.00
	12	0.00	0.00	100.00
	24	0.00	0.00	100.00
	36	0.00	0.00	100.00

Table 5.2 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$$

Forecast error in	Horizon	Shock η_{nt}	η_{r1t}	η_{r2t}
Germany				
e	1	4.40	95.50	0.10
	3	4.60	93.02	2.39
	6	4.63	92.95	2.42
	9	4.63	92.95	2.42
	12	4.63	92.95	2.42
	24	4.63	92.95	2.42
	36	4.63	92.95	2.42
r	1	0.00	99.99	0.01
	3	0.06	97.69	2.27
	6	0.06	97.65	2.29
	9	0.06	97.65	2.29
	12	0.06	97.65	2.29
	24	0.06	97.65	2.29
	36	0.06	97.65	2.29
y	1	0.00	0.00	100.00
	3	0.50	0.31	99.19
	6	0.57	0.34	99.08
	9	0.57	0.35	99.08
	12	0.57	0.35	99.08
	24	0.57	0.35	99.08
	36	0.57	0.35	99.08

Table 5.3 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$$

Forecast error in	Horizon	Shock η_{nt}	η_{r1t}	η_{r2t}
Canada				
e	1	23.07	76.82	0.10
	3	23.28	76.59	0.14
	6	23.28	76.59	0.14
	9	23.28	76.59	0.14
	12	23.28	76.59	0.14
	24	23.28	76.59	0.14
	36	23.28	76.59	0.14
r	1	0.00	99.96	0.04
	3	0.00	99.96	0.04
	6	0.00	99.96	0.04
	9	0.00	99.96	0.04
	12	0.00	99.96	0.04
	24	0.00	99.96	0.04
	36	0.00	99.96	0.04
y	1	0.00	0.00	100.00
	3	0.00	0.00	100.00
	6	0.00	0.00	100.00
	9	0.00	0.00	100.00
	12	0.00	0.00	100.00
	24	0.00	0.00	100.00
	36	0.00	0.00	100.00

Table 5.4 Percent forecast error variance due to each shock

$$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$$

Forecast error in	Horizon	η_{nt}	Shock η_{r1t}	η_{r2t}
France				
e	1	2.20	97.77	0.03
	3	2.19	97.46	0.35
	6	2.26	96.70	1.04
	9	2.27	96.67	1.06
	12	2.27	96.67	1.06
	24	2.27	96.67	1.06
	36	2.27	96.67	1.06
r	1	0.00	99.99	0.01
	3	0.04	99.28	0.68
	6	0.04	98.48	1.47
	9	0.04	98.46	1.49
	12	0.04	98.46	1.49
	24	0.04	98.46	1.49
	36	0.04	98.46	1.49
y	1	0.00	0.00	100.00
	3	0.01	1.06	98.93
	6	0.01	1.46	98.54
	9	0.01	1.47	98.53
	12	0.01	1.47	98.53
	24	0.01	1.47	98.53
	36	0.01	1.47	98.53

Table 5.5 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{r1t}	η_{r2t}
Italy				
e	1	9.05	90.83	0.12
	3	10.81	88.96	0.22
	6	12.86	86.01	1.14
	9	13.58	85.17	1.25
	12	13.84	84.89	1.27
	24	14.04	84.70	1.27
	36	14.04	84.69	1.27
r	1	0.00	99.98	0.02
	3	0.85	99.01	0.14
	6	4.24	93.78	1.99
	9	4.50	93.28	2.21
	12	4.51	93.23	2.26
	24	4.51	93.22	2.26
	36	4.51	93.22	2.26
y	1	0.00	0.00	100.00
	3	3.41	0.16	96.43
	6	4.20	0.51	95.28
	9	4.31	0.53	95.16
	12	4.33	0.53	95.14
	24	4.34	0.54	95.13
	36	4.34	0.54	95.13

Table 5.6 Percent forecast error variance due to each shock

$X_t = [\Delta e_t, \Delta r_t, \Delta y_t]'$

Forecast error in	Horizon	Shock η_{nt}	η_{r1t}	η_{r2t}
U.K.				
e	1	9.58	90.14	0.29
	3	9.90	89.80	0.30
	6	9.90	89.80	0.30
	9	9.90	89.80	0.30
	12	9.90	89.80	0.30
	24	9.90	89.80	0.30
	36	9.90	89.80	0.30
r	1	0.00	99.32	0.68
	3	0.00	99.28	0.72
	6	0.00	99.28	0.72
	9	0.00	99.28	0.72
	12	0.00	99.28	0.72
	24	0.00	99.28	0.72
	36	0.00	99.28	0.72
y	1	0.00	0.00	100.00
	3	0.00	0.00	100.00
	6	0.00	0.00	100.00
	9	0.00	0.00	100.00
	12	0.00	0.00	100.00
	24	0.00	0.00	100.00
	36	0.00	0.00	100.00