EXCHANGE RATES, MONETARY POLICY, AND THE INTERNATIONAL TRANSMISSION MECHANISM

by

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Abstract

The three chapters of this thesis address two questions. First, how are real and nominal exchange rates between different national currencies determined? Second, how does this determination influence the international transmission of macroeconomic fluctuations and, especially, monetary policy disturbances?

Chapter 1 comprises an empirical evaluation of long-run purchasing power parity as a theory of equilibrium nominal exchange rate determination for the post-Bretton Woods data. Structural time series methods are used to identify bivariate moving average representations of nominal exchange rates and relative goods prices and to test whether these empirical representations are consistent with the implications of purchasing power parity. Long-run purchasing power parity can be unambiguously rejected for the G-7 countries. There are permanent deviations from parity which account for almost all of the variance of real exchange rates, and which are driven by permanent disturbances to nominal rates which are never reflected in relative goods prices.

Chapter 2 presents an empirical evaluation of the hypothesis that the global Depression of the 1930's was attributable to international transmission of (idiosyncratic) U.S. monetary policy actions through the International Gold Exchange Standard - fixed exchange rate - regime. Specifically, the analysis evaluates whether the interwar output collapse in Canada was caused by transmitted U.S. monetary policy disturbances. A multivariate structural time series representation of the Canadian macroeconomy is estimated which is consistent with the dynamic and long-run equilibrium properties of a Mundell- Fleming small open economy model and in which U.S. data represent the 'rest of the world'. The empirical results show that U.S. monetary disturbances play a negligible role for both Canadian and U.S. output movements in the 1930's. Permanent common *real* shocks to outputs can account for the onset, depth and duration of the Depression in both economies. There is little evidence to support a Gold-Standard transmitted global output collapse through the transmission mechanisms usually associated with purchasing power parity theories of real exchange rate determination.

Chapter 3 develops an alternative theory of real and nominal exchange rate determination and of the international transmision mechanism which can account for many stylized facts regarding the empirical behaviour of real and nominal exchange rates that long-run purchasing power parity fails to explain. In a two-country, two-currency overlapping generations model, the role of optimal portfolio choices between internationally traded assets is emphasized - rather than goods market trade - as the source of currency demands. These demands, and supplied of assets generated by domestic monetary policies, determine both real and nominal exchange rates. Here, monetary

policy changes can induce permanent international and intra-national reallocations through real exchange rate and real interest rate adjustments. This transmission mechanism differs markedly from that implied by purchasing power parity.

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I dedicate this thesis to my family.

0 Introduction

The three chapters of this thesis each address some dimension of the following two questions. First, how are real and nominal exchange rates between different countries' currencies determined? Second, what is the rôle of this determination in the international transmission of macroeconomic fluctuations and, especially, monetary policy disturbances?

The hypothesis of purchasing power parity dominates contemporary international macroeconomic analysis as a theory of real and nominal exchange rate determination. That free international trade in consumption goods ultimately determines the relative prices of the fiat currencies of different countries is a key implication of most two-country (monetary) models of nominal exchange rate determination and international fluctuations. More generally, many international macroeconomic models assume that international goods market arbitrage will equalize the common currency price of a given basket of goods in spatially separated economies under *either* market determined *or* institutionally fixed nominal exchange rates. Under this assumption, there are no disturbances that (permanently) move the real exchange rate from its (initial) mean value of unity. Equivalently, there are no (permanent) disturbances to purchasing power parity. (Of course, under flexible rates it is the nominal exchange rate that adjusts to re-establish parity following disturbances to relative goods prices, while under fixed rates the work of re-adjustment to parity is achieved through national price level movements.)

In addition, the assumption that purchasing power parity holds under any given nominal exchange rate regime implies that a particular set of mechanisms operate for the international transmission of macroeconomic disturbances. These implications, also, are reflected in most contemporary analyses of international business cycles.

It has long been accepted that parity values for common currency goods' prices will not be observed to hold instantaneously. Purchasing power parity is now typically viewed (in fact, generated by general equilibrium two-country models) as a 'long-run' or steady state relationship; as one that holds in the absence of changes in fundamental macroeconomic variables. Yet there exists mixed evidence on the validity of this theory of (long-run) real and nominal exchange rate determination.

Alternative methods for the empirical evaluation of long-run purchasing power parity have been employed and applied to various data sets with mixed and sometimes ambiguous results. Further, casual observation suggests that, for the post-Bretton Woods flexible exchange rate era, real and nominal exchange rates move together very closely and appear to be approximately equally volatile. This observation may be viewed as a manifestation of the failure of purchasing power parity in this data. Finally, the behaviour of real exchange rates not only fails to accord with purchasing power parity doctrine during many different exchange rate regimes, but it also significantly differs across regimes. This, again, is inconsistent with the presence of regime-invariant parity relations between common currency goods prices.

In this thesis I study a number of aspects of exchange rate determination - both empirically and theoretically - and its implications for international transmission of monetary and real economic disturbances across countries, with a view to evaluating the validity of purchasing power parity theory.

Chapter 1 comprises an empirical evaluation of long-run purchasing power parity as a theory of equilibrium *nominal* exchange rate determination in the post-Bretton Woods data. Structural time-series methods are used to identify bivariate stochastic representations of nominal exchange rates and relative goods prices and to test whether these are consistent with the implications of purchasing power parity. The bivariate representations are capable of separately identifying and directly measuring transitory and permanent shocks to real and nominal exchange rates and to relative prices. Using these methods, the hypothesis of purchasing power parity can be unambiguously rejected for the G-7 countries and I find that sources of real and nominal exchange rate variation are orthogonal to sources of relative goods price movements. There are permanent deviations from purchasing power parity which account for almost all of the variance of real exchange rates in this sample at forecast horizons exceeding six to twelve months. These deviations are almost entirely driven by permanent disturbances to nominal exchange rates which do not affect relative prices at any horizon.

Chapter 2 comprises an empirical evaluation of the hypothesis that aggregate fluctuations in the U.S., and U.S. monetary policy actions in particular, were the source of the inter-war Depression experience of Canada. Specifically, using Canada as a case-study the paper assesses the pre-eminent view that the international nature of the Great Depression can be explained by transmission of such U.S. monetary policy disturbances through prices under the fixed nominal exchange rate (International Gold Standard) regime.

A multivariate structural time-series model is estimated of the Canadian macroeconomy. This empirical representation is consistent with the long-run and dynamic implications of a standard small open economy model in which the U.S. represents the 'rest of the world' relative to Canada and in which Canada is assumed to be on a fixed nominal exchange rate. Weak (or relative) purchasing power parity is found to hold here, but the disturbances identified with U.S. monetary policy shocks appear to play an insignificant role for even short-run output fluctuations in Canada. While these policy disturbances strongly influence the time-paths of both Canadian and U.S. money and prices they have no significant real balance, relative price (real exchange rate) or output effects. It is not possible to identify aggregate fluctuations in this small, open economy with externally originating macroeconomic disturbances that are transmitted through a mechanism associated with the fixed exchange rate (long-run purchasing power parity) regime. These results are, of course, predicated on an empirical representation that assumes the existence of such mechanisms.

Chapter 3 presents an alternative theory of real and nominal exchange rate determination that can account for the stylized facts of real and nominal exchange rate behaviour that long-run purchasing power parity fails to explain. In the model presented, the role of optimal portfolio choices between internationally traded assets is emphasized as the source of demands for alternative currencies, rather than international trade in consumption goods. The consequences of changes in monetary policy, the nominal exchange rate regime, and financial market regulations for real and nominal exchange rates and for asset returns are studied. The results suggest that there exist important mechanisms for domestic and international reallocations through these media which significantly differ from those associated with purchasing power parity theories of exchange rate determination. In particular, the role of monetary policy in international transmission for an economy where asset market interactions dominate exchange rate determination is quite different from that typically assumed; in fact, here monetary policy can generate permanent international and intra-national reallocations through real exchange rate and real interest rate adjustments.

The model presented in Chapter 3 suggests that future empirical evaluation of the determinants of real and nominal exchange rates, and empirical work designed to identify sources of international transmission of macroeconomic disturbances, should account for variables, relationships and transmission mechanisms that are not illuminated by purchasing power parity theories of exchange rates.

The following overviews provide more detailed description of the three Chapters.

0.1 Overview: 'Identifying Disturbances To Purchasing Power Parity'

In Chapter 1, titled 'Identifying Disturbances To Purchasing Power Parity', a new methodology for identifying disturbances to real exchange rates is proposed. This allows both an evaluation of the Casselian purchasing power parity hypothesis and identification of specific sources of deviations from bilateral parity relations between nominal exchange rates and relative goods prices. The paper critiques existing univariate tests of purchasing power parity. The empirical implications of purchasing power parity for the bivariate time-series properties of the nominal exchange rate and relative prices are described and an associated bivariate econometric representation is presented. A methodology for testing long-run purchasing power parity is derived that uses these bivariate representations and this is applied to data from the floating exchange rate period for the G-7 countries.

Equilibrium models of exchange rate determination that deliver purchasing power parity as a steady state relationship have the following empirical implications. First, any permanent stochastic disturbance to relative goods prices (due to permanent shocks to relative money stocks and outputs, for example) is both equally and permanently reflected in the nominal exchange rate. Second, any other disturbance to relative prices or nominal exchange rates should be purely transitory for both variables. Consequently, nominal exchange rates and relative prices should be observed empirically to share a common stochastic trend, and the real exchange rate should exhibit mean reversion or purely transitory dynamics around a fixed mean. Empirical evidence for such mean reversion is mixed.

Application of standard univariate tests of mean reversion to real exchange rate data dominates empirical evaluation of long-run purchasing power parity. Yet it is well known that such tests have low power to discriminate between variables which exhibit high degrees of persistence and those that have permanent components. In particular, we know that any univariate series found to be non-stationary by such tests comprises both a permanent and a transitory component with the former having arbitrarily small variance. Univariate tests cannot inform on the relative size of these permanent and transitory components in non-stationary univariate data series. Such tests are, therefore, argued to be uninformative for evaluating long-run purchasing power parity.

An alternative method for testing purchasing power parity is proposed. This involves identification of a bivariate structural moving average representation for the nominal exchange rate and relative prices which is consistent with, but does not impose, the maintained hypothesis of long-run purchasing power parity. This representation can express the current level of the nominal exchange rate and of relative prices as the outcome of contemporaneous and historical realizations of two fundamental disturbances. In particular, it decomposes the variance of these two variables into sources due to permanent and purely transitory disturbances, and allows direct measurement of the relative importance of each type of disturbance for the variance of the real exchange rate.

The common stochastic trend implication of purchasing power parity implies that the reduced form parameterization of this bivariate system takes the form of a vector error correction model. This is estimated and inverted to generate a reduced form moving average representation. Purchasing power parity is then evaluated in the following ways.

A structural moving average representation of an equilibrium exchange rate model can always be identified from a reduced form representation by imposing restrictions on the long-run responses of the nominal exchange rate and relative prices to particular types of disturbance. First, by imposing the restriction that relative prices have a zero long-run (infinite horizon) response to one shock, an empirical representation is derived which decomposes fluctuations in nominal exchange rates and relative prices into sources due to disturbances which permanently affect relative prices and to disturbances which only transitorily affect relative prices. Under the maintained model, permanent relative price disturbances should have an equal permanent effect on the nominal exchange rate. Transitory relative price disturbances should induce purely transitory nominal exchange rate dynamics. Inspection of the estimated long-run multiplier matrix for the moving average provides a (weak) test of the satisfaction of these conditions. Analysis of the impulse response functions of the two variables and of their forecast error-variance decompositions then informs on whether any permanent real exchange rate disturbances found, due to the failure of either of these conditions, are large and significant.

Alternative decompositions are also considered. A permanent-transitory decomposition for the nominal exchange rate should deliver identical results as that for relative prices under the maintained hypthesis. A decomposition which imposes an equal long-run effect for both variables of one disturbance should deliver an equal (possibly zero) effect for both variables of the second disturbance. Finally, purchasing power parity can be imposed directly on the bivariate system and the implied short-run dynamics of the system inspected for their consistency with theory. In fact, under the maintained hypothesis that long-run purchasing power parity holds, these four alternative representations should be identical (subject to sampling error).

The models are estimated and small sample statistical inference based on standard errors and biases computed by Monte Carlo integration. The following empirical results are obtained for monthly data over the sample period 1975:1-1991:12. For no G-7 country does purchasing power parity hold according to the criteria discussed for bilateral nominal exchange rates against the $US. This is true whether consumer prices or wholesale and producer prices are employed. Some striking empirical regularities are found.

While permanent shocks to relative prices typically do have approximately equal long-run effects for nominal exchange rates, such disturbances account for a negligible fraction of nominal *and* real exchange rate variance. However, for all countries there are large and significant permanent movements of the nominal exchange rate due to shocks which are identified as purely transitory for relative prices. In fact, these transitory relative price disturbances insignificantly affect (the variance of) relative prices at all horizons, yet they can account for more than 50% of both nominal and real exchange rate variation in every case. There is, then, a large and significant permanent component in real exchange rates due to disturbances that never affect relative goods prices but generate almost all nominal exchange rate fluctuations. It is such nominal exchange rate disturbances that can account for the empirical observation that real and nominal exchange rates are approximately equally volatile.

These results are mirrored in decompositions that impose equal long-run effects for one of the two disturbances for nominal exchange rates and relative prices; this disturbance turns out to be exactly (has identical properties to) the permanent shock to relative prices identified in the permanent/transitory relative price decompositions.

In the permanent/transitory nominal exchange rate decompositions, both the identified permanent and transitory disturbances to the nominal exchange rate cause permanent deviations from purchasing power parity. This decomposition generates permanent relative price responses following both types of nominal rate disturbance, while the variance of nominal exchange rates is primarily attributable to permanent nominal exchange rate shocks. These results are consistent with the preceding finding that nominal exchange rates and relative prices do not share a common permanent component, and with the previous observation that relative price movements appear to be driven at both short and long horizons by (their 'own') permanent disturbances.

Finally, the decomposition that imposes long-run purchasing power parity generates transitory relative price shocks with very long-lived effects for real exchange rates, and which induce exchange rate and relative price dynamics that are difficult to reconcile with theory.

The results suggest that sources of variance in exchange rates and relative prices are orthogonal. Permanent deviations from purchasing power parity are observed, in almost every sample studied, due to permanent nominal exchange rate shocks which do not affect relative prices at any horizon.

Some extensions of the empirical investigation are considered. In particular, finer decompositions of variance might allow a more structural interpretation of the permanent nominal and real exchange rate shocks identified here. For example, decompositions of exchange rate variation using data on (relative) money stocks and outputs to identify explicitly monetary and real disturbances may be appropriate. Moreover, as shown in Blanchard and Quah (1989), results derived from bivariate models are conditional on the appropriateness of an aggregation assumption on the transitory and permanent disturbances identified. If multiple underlying disturbances of either type generate different dynamics in the two variables, the assumption that all permanent and all transitory disturbances can be treated as single (average) disturbances is invalid. Richer decompositions of exchange rate variance could help alleviate this potential misspecification problem, in addition to generating more information on the sources of real and nominal exchange rate determination.

0.2 Overview: 'A Small Open Economy In Depression: Lessons From Canada In The 1930's'

In Chapter 2, titled 'A Small Open Economy In Depression: Lessons From Canada In The 1930's', an empirical investigation of the sources of the Great Depression in Canada is conducted. The goals of the paper are to contribute to the economic history of the Canadian Depression experience and to generate evidence towards an explanation of the international nature of the output collapse in the 1930's. In particular, I seek to evaluate the role of the fixed exchange rate regime in propagating macroeconomic disturbances across national (economic) borders.

It is argued that, because Canada is well characterized as a small open economy, the Canadian data provide a fertile testing ground for theories regarding international transmission of business cycle fluctuations. Two facts suggest that especially powerful transmission mechanisms may have operated between Canada and the U.S. during the Great Depression. First, the U.S. was Canada's most important trading partner during the 1930's and, second, the Canadian government maintained a fixed exchange rate against the U.S. dollar throughout the 1930's despite the breakdown of the interwar gold exchange standard. Consequently, analysis of Canadian interwar data can potentially help explain if and how the Depression was propagated internationally from the U.S. economy.

Given these observations, the paper addresses three questions. First, what were the sources of aggregate fluctuations in Canada during the years, 1929-1933, of output collapse ? Second, were aggregate fluctuations in Canada during this era primarily caused by disturbances transmitted from the U.S. economy as the conventional view of the source of *international* output collapse asserts? Third, if international transmission from the U.S. economy was the source of Canadian output collapse, were monetary disturbances identifiable with Federal Reserve policy actions the most important factor, as frequently proposed in explanations both of the U.S. and global Depression ?

Two alternative views of the international nature of the Depression are considered and empirically evaluated. First, an extensive literature on the U.S. Depression assumes that the global output collapse reflected international transmission through some combination of goods and financial market forces of a recession originating in the U.S., initiated by Federal Reserve stringency in 1928, and exacerbated by financial crises following the Stock Market collapse during which the Federal Reserve failed to provide necessary liquidity to the banking system. In contrast, analyses of the Canadian and European Depression experience, while recognizing the importance of international transmission, also emphasize the role of idiosyncratic factors in each country's economic history. In the Canadian case, recognition is given to the peculiar vulnerability of the small open economy to fluctuations in the external demand for her primary export goods. However, structural changes in the late 1920's reflecting the end of prairie settlement and of the post-war investment boom in new primary manufacturing (processing) industries are also proposed to have induced recession.

An empirical representation of the Canadian economy is developed in which Canada is explicitly modeled as a small open economy on a fixed exchange rate and U.S. data is used to represent the 'rest of the world'. Specifically, a structural moving average representation of the Canadian economy is proposed in which the current values of Canadian variables are described by contemporaneous and historical realizations of a set of macroeconomic disturbances which may originate domestically, externally or be common to the domestic and external economies.

Monthly, seasonally adjusted data for the sample period 1925:1-1939:12 on industrial production, the M1 money stock and wholesale prices for the two countries is analyzed prior to estimation. Tests for common stochastic trends in the U.S. and Canadian series reveal that outputs, money stocks and prices share such trends. Consequently, I can identify three disturbances which have equal, permanent effects on the levels of Canadian and U.S. variables. The first is interpreted as a common supply shock which drives the long-run trend in output for both economies and which may permanently affect both money stocks and price levels. The second is interpreted as a policy-driven money supply shock which generates a nominal long-run trend in each economy. This can be viewed as the outcome of Federal Reserve policy actions and is transmitted to the Canadian economy through the fixed exchange rate. The money supply shock is identified by assuming long-run neutrality of monetary shocks for output. The third is a permanent disturbance to the demand for real balances in each economy. This is interpretable as a common shock to the demand for liquidity, deriving from common asset market conditions, and is identified by allowing only price level adjustments to this disturbance in the long-run.

I also identify two country-specific disturbances by assuming that sources of aggregate fluctuations originating in Canada have no immediate (direct) impact on U.S. variables. These are purely transitory disturbances which can be interpreted as real expenditure or demand shocks, in the U.S. case, and also as transitory domestic monetary disturbances in the Canadian case.

The moving average representation for the six variables of interest is estimated under these identifying assumptions. I analyze the estimated structural innovations, the impulse response functions, forecast error variance decompositions and historical decompositions of variance which are derived from this dynamic representation. The results obtained are as follows.

The estimated structural innovations do identify the U.S. monetary contraction in 1928, and the attendant rise in transactions money demand emphasized by Hamilton (1987) and Field (1984).

However these shocks are absorbed by prices and have an insignificant effect on output in both Canada and the U.S. Similarly, I find evidence in the estimates of deflationary monetary policy in 1930, and the historical decompositions reveal a significant unanticipated money stock contraction during 1931 and 1932 to which Friedman and Schwartz (1963) attribute the depth and persistence of the U.S. Depression. Yet the former has no significant output effects in the historical decompositions and the latter I find to be primarily an endogenous response to the permanent output disturbances as argued by Temin (1976). Idiosyncratic U.S. demand disturbances during 1929 can be identified, to which Temin (1976) and Romer (1990) attribute significance, but do not induce important output effects in either economy. Consequently, these results reject explanations of the global Depression which emphasize international transmission of autonomous monetary and real disturbances unique to the U.S. economy.

I find that the onset, depth and persistence of the Depression in both Canada and the U.S. is attributable to the common, permanent output (supply) shock leaving little significant role for idiosyncratic disturbances in either economy. From 1929-1936, the twelve month ahead forecast error in both output series is almost entirely due to this disturbance. Similarly, I find that the level of output through this sub-sample is almost exclusively accounted for by the cumulative effects over time of the supply shock. There is a striking symmetry in the behaviour of production in the two countries for the Depression subsample.

Some interpretations are offered. The results are consistent with Fisher's (1933) hypothesis that declines in expected and actual productivity initiated both the 1929 U.S. recession and the Stock Market Crash in October of that year. They are also supportive of explanations for the Depression such as Bernstein (1987) and Safarian (1959) that emphasize secular factors, and the importance of supply shocks during the 1931-1933 subsample is consistent with Bernanke's (1983) assertion that disruptions to bank intermediated credit during the banking crises had real, long-lived effects for efficiency, productivity and output. While the results interpret the Depression as an international, 'collapse in trend' event, the underlying source of that trend cannot be uncovered. Finally, it is observed that if secular factors which were continental, if not global, can explain the Depression in Canada and the U.S., this provides a potential rationalization for observed synchronicity in the timing and pattern of international output collapse.

0.3 Overview: 'Money, Banking And The Determination Of Real And Nominal Exchange Rates'

Chapter 3, titled 'Money, Banking And The Determination Of Real And Nominal Exchange Rates', presents a theoretical model of real and nominal exchange rate determination. The objective of this analysis is to develop a model that can account for a number of important stylized facts regarding the behaviour of real and nominal exchange rates in the post-war data; namely, the failure of purchasing power parity and several manifestations of that fact.

A two country, single good, pure exchange model is considered in which the single good is non-traded (subject to prohibitive transportation costs). In each country there is a government which issues both fiat currency and interest-bearing bonds. While trade in goods is limited, international trade in these four assets is unrestricted. It is, then, the monetary policies that control supplies of these assets, and the demands for assets by private agents in international capital and currency markets, that ultimately determine real and nominal exchange rates.

The demands for alternative currencies and for bonds are generated by the following mechanism. Within each country there are two, symmetric locations and agents move between domestic and international locations stochastically, with stochastic relocation playing the role of liquidity, or portfolio, preference shocks. In particular, if relocated, agents must carry with them currency which is assumed to have superior liquidity characteristics over bonds in the presence of spatial separation and limited communication between locations. Furthermore, inter-location exchange requires the currency of the country in which the seller is located so that only the currency of ultimate destination is of value to an agent, ex post, if relocated. These assumptions, in an environment in which currency is dominated in rate of return by the bonds of each country, induces *ex ante* portfolio diversification among all four assets in the economy by private agents.

In fact, since stochastic relocation plays the role of liquidity preference shocks in the Diamond-Dybvig (1984) model, banks naturally arise in this economy to insure agents against their random needs for currency-specific liquidity; against the risk of premature asset liquidation. To provide this insurance, banks in each country hold both foreign and domestic currencies as reserves and in addition invest in interest-bearing government bonds.

Since trade in goods between countries is limited, purchasing power parity need not hold. The determination of the real exchange rate is examined in a model where all markets are competitive and clear at each date, all prices are flexible, and all agents have equal access to all asset markets. Real exchange rate determination is analyzed under a variety of policy regimes, including fixed and flexible exchange rates, and regimes which differ with respect to the degree of domestic or foreign bank regulation and the presence or absence of exchange controls.

The results obtained are as follows. Monetary policy, portfolio preference parameters and relative endowments are all fundamentals in any steady state equilibrium for both real and nominal exchange rates. The importance of monetary factors is consistent with recent empirical evidence supporting an important role for nominal shocks in real exchange rate fluctuations. There is a unique steady state equilibrium under both flexible and fixed exchange rates which is, for identical money growth rates, invariant to the choice of regime. In addition, the choice of nominal exchange rate value under fixed nominal rates has no allocative consequences and does not affect the equilibrium real exchange rate at any date.

Under a regime of flexible exchange rates, an increase in the rate of growth of the domestic (foreign) money supply causes the real interest rate to rise and generates a real and nominal depreciation of the domestic (foreign) country's currency. The former effect is due to the fact that money creation finances debt repayment, while the latter is due to the fact that an increase in the money growth rate of either country taxes the holders of that country's currency thereby reducing their demand for the goods of that country. Goods markets are re-equilibrated by a real exchange rate movement that raises the purchasing power of foreign (domestic) agents in the domestic (foreign) economy. In addition, the impact on the initial nominal exchange rate of monetary changes is necessarily equal to the impact on the real exchange rate, which is consistent with the observation that real and nominal exchange rates are approximately equally volatile. Under a regime of fixed exchange rates, an increase in the rate of growth of (all) money supplies tends to move the real exchange rate, but the impact is necessarily smaller than that under a regime of flexible rates. This finding is consistent with the stylized fact that real exchange rate movements tend to be more pronounced under flexible than under fixed exchange rate regimes.

The use of reserve requirements or exchange controls by a foreign country will also influence the real interest rate and real exchange rate of the domestic country. An increase in the foreign country's reserve requirements (a tightening of the foreign country's exchange controls) tends to raise (reduce) the world real interest rate and to raise (have an ambiguous effect for) the domestic country's real exchange rate. Both reserve requirements and exchange controls affect the efficacy of monetary policy changes in manipulating real and nominal exchange rates. These results hint at the importance of reductions in exchange controls and reserve requirements since 1973 in helping to account for the observed change in real exchange rate behaviour since that date relative to the Bretton Woods era.

Notably, while the effects of monetary policy changes in the theoretical model can account for the stylized facts of real and nominal exchange rate behaviour cited here, changes in real factors (relative endowments) have counterfactual properties. The impact on the real exchange rate of a change in relative endowments is identical under fixed and flexible exchange rate regimes, and the real exchange rate movement induced by such a change is never reflected in nominal exchange rates under flexible nominal exchange rate regimes.

Several extensions of the analysis can be contemplated. These include an investigation of more sophisticated monetary policies, more general utility functions, the introduction of more stochastic elements, and an analysis of a version of the model with production. The latter extension will permit an analysis of how output levels, real and nominal exchange rates, and price levels are jointly determined. It will thereby make possible statements about how policies that are designed to move real exchange rates in favour of a particular country affect that country's level of development.

1 CHAPTER 1: Identifying Disturbances To Purchasing Power Parity

1.1 Introduction

The proposition that purchasing power parity (PPP) determines the long-run equilibrium value of freely traded currencies is both a central proposition of traditional open-economy macroeconomic representations and a key implication of equilibrium in many two-country monetary business cycle models. This proposition implies that permanent disturbances to relative goods prices should be reflected one-for-one in nominal exchange rates and that nothing else (no transitory price shock) matters at distant horizons for the variance of either variable. Consequently, the real exchange rate (the PPP deviation) should exhibit long-run mean reversion in response to either type of disturbance; a long-run neutrality result holds. Yet tests of long-run PPP based on analyses of the univariate properties of real exchange rates have returned mixed results.

Here, bivariate time-series representations of nominal exchange rates and relative prices are used to identify and measure transitory and permanent deviations from PPP. In contrast to univariate models, both the specification and identification of these representations is conditional on information derived from economic models that deliver PPP as a long-run equilibrium condition. Consequently, there are a number of well-defined implications for the bivariate system that must be satisfied under the maintained hypothesis, each of which takes the form of a long-run neutrality proposition. Application of the bivariate methodology to G-7 data for the floating exchange rate period reveals that several of these neutrality propositions are consistently violated across countries and that long-run PPP can be rejected without exception.

In its strongest form PPP asserts that international goods market arbitrage ensures instantaneous equalization in spatially separated economies of the common currency price of a given commodity basket. While impediments to free trade in goods may prevent the relation from holding exactly, changes in common currency prices are assumed to be exactly contemporaneously correlated by weaker forms of the doctrine. Under flexible exchange rate regimes, market determined spot currency prices eliminate goods market arbitrage opportunities. Static open economy models in the spirit of the Mundell-Fleming monetary approach assume satisfaction of such arbitrage conditions, yet casual observation from the floating exchange rate regime reveals that no such instantaneous PPP relation holds in the data. Specifically, the data are characterized by volatile currency prices which diverge widely and persistently from the parity values implied by relative price series.

Yet, since at least Cassel (1918) it has been recognized that PPP should be viewed as an *equi-*

librium rather than instantaneous condition for exchange rate determination. Traditional models adapted to incorporate dynamics (Dornbusch (1976) and Mussa (1982) are leading examples) imply that any observed divergences from PPP in the data represent purely transitory deviations from equilibrium. Slower adjustment of goods than asset prices following unpredictable (permanent) macroeconomic disturbances causes nominal exchange rates to overshoot the new fundamental level of relative goods prices. Two-country, two currency dynamic general equilibrium models, extending Lucas's (1982) framework, derive PPP as the implication of an optimal consumption plan for a rational, forward looking agent who transacts in two, distinct goods markets which require the agent to offer different currency units in exchange for goods.[1] Equilibrium relative goods prices, and hence nominal exchange rates, are determined endogenously as functions of cross-country differentials in fundamentals; taste, technology and money stock parameters. In the absence of new disturbances to these fundamentals this equilibrium is realized.[2]

These models each have a version of PPP as a long-run equilibrium condition for nominal exchange rate determination, while allowing for transitory dynamics from equilibrium characterized by PPP deviations. While alternative hypotheses exist,[3] PPP still dominates as a condition for long-run exchange rate determination in open economy models.

Ultimately, whether PPP can explain real and nominal exchange rate behaviour in the long-run is an empirical issue that cannot be resolved by mere inspection of the data but requires estimation of long-run equilibria. Most tests of long-run PPP have been predicated on the univariate properties of the real exchange rate. Such tests use the fact that if equilibrium currency values are pinned down by goods market arbitrage then their long-run (low-frequency) behaviour will reflect this. Bilateral nominal exchange rates and relative goods prices should share a common permanent component, or cointegrate in the sense of Granger (1983), and their log difference, the real exchange rate, should be covariance stationary exhibiting purely transitory deviations from mean. A finding of a non-stationary real exchange rate is then taken to imply the failure of long-run PPP.[4]

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[1] See, for example, Grilli and Roubini (1992) and Schlagenhauf and Wrase (1992a,1992b).

[2] Grilli and Roubini (1992) show how asset market disturbances originating in government open market operations can generate liquidity effects for equilibrium exchange rates which are 'non-fundamental' (have no relative price effects). However, these liquidity effects have zero expectation.

[3] See Blanchard and Watson (1982), Meese (1986) and Frankel and Froot (1990) in which rational and irrational speculative bubbles in exchange rates are posited as potential explanations for apparent failures of PPP to hold in the data. In general, models with extrinsic uncertainty can explain volatility of real and nominal exchange rates which are unrelated to movements in fundamentals with sunspot equilibria.

[4] Studies that employ univariate tests of purchasing power parity are too numerous to document fully. Roll (1979), Meese and Singleton (1982), Adler and Lehmann (1983), Mussa (1986) and Diebold (1988) are among those studies that reject long-run PPP with univariate non-stationarity tests applied to real exchange rates. (These tests originate in the work of Dickey and Fuller (1979, 1981) and Phillips (1987) in particular.) By contrast, Diebold, Husted and Rush (1991), Cheung (1993) and Cheung and Lai (1993) reject the martingale hypothesis in long spans of data, modeling real exchange rates as long memory but *fractionally* integrated processes. Huizinga (1987), Kaminsky (1988), and

Yet there are two (now familiar) objections to such a univariate approach which together imply that univariate stationarity tests have (arbitrarily) low power to detect the presence of long-run PPP in the data. First, the low power of standard tests for non-stationarity to discriminate between highly persistent and non-stationary time-series has long been recognized.[5] In particular, Cochrane (1991) and Quah (1992) demonstrate that any stochastic process which can be identified as non-stationary has a permanent component with arbitrarily small variance. Yet univariate representations of such processes can neither identify nor measure the relative size of permanent and transitory components of a series without imposing additional structure on the covariance properties of the two components (which derives from information extraneous to the empirical model specified). Consequently, the finding of a non-stationary real exchange rate may have little statistical or economic relevance.

A second, and related objection, is that univariate methods cannot inform on the sources of PPP deviations relative to any economic model. In the absence of information that permits structural interpretation of the permanent (or long-lived) components frequently found in real exchange rates, univariate tests for stationarity have little insight to offer on the validity of specific theoretical propositions regarding exchange rate determination.

In this paper, structural vector autoregressions (VAR's) are used to generate more informative tests of long-run PPP. Long-run neutrality propositions about the effects of alternative disturbances for real exchange rates can be straightforwardly evaluated when the maintained model allows for permanent components in both nominal exchange rates and relative prices. The class of models that delivers PPP as a long-run relation, while having no unique set of implications for transitory exchange rate and relative price dynamics, does have a unique set of implications for the effects of permanent disturbances for relative prices and nominal exchange rates. Specifically, any permanent disturbance to relative goods prices, whether due to monetary or real shocks, has an equal permanent effect on nominal exchange rates. All other disturbances in this class of models have no permanent effect for either variable. Long-run PPP therefore implies that two long-run neutrality propositions should hold for the real exchange rate when nominal rates and relative prices are subject to permanent disturbances.

A bivariate structural moving average representation is identified which expresses these two variables as the outcome of current and historical realizations of permanent and transitory distur-

Grilli and Kaminsky (1991) find evidence of mean reversion in real rates using univariate variance ratio tests, while Abuaf and Jorion (1990) following Hakkio (1984) also support long-run PPP when cross-sectional information is incorporated into variance ratio statistics.

[5]See, for example, Schwert (1987) and Gregory (1991) and, in the exchange rate context, Hakkio (1984)

bances to relative prices, which is parameterized as a bivariate VAR of an error-correcting form in relative goods prices and nominal exchange rates. [6] This allows long-run hypotheses to be tested directly. Estimates of the infinite horizon multipliers for permanent and transitory relative price shocks are derived and inspected with the impulse response functions for evidence that the long-run restrictions are satisfied. Forecast error-variance decompositions then inform on the relative size of the implied transitory and permanent components in real exchange rates.

Three other, complementary tests of long-run PPP are conducted. The maintained model implies that a bivariate representation in which permanent and transitory disturbances to nominal exchange rates are identified should mirror exactly that in which a permanent/transitory relative prices variance decomposition is invoked, at least in its long-run behaviour. This representation is estimated and results compared to those from the relative price decomposition described above. The maintained model also implies that if an underlying structure is identified in which one disturbance is imposed to have an equal long-run effect on relative prices and nominal exchange rates then the second disturbance should also have an equal long-run impact on the two variables which may be zero. The results from this model should reflect those for the preceding two. Finally, if a structure is identified in which long-run PPP is imposed, the estimated dynamics of that system should be reconcilable with at least one standard idea about the effects over time of permanent and transitory relative price shocks in economic models that predict long-run PPP and, under the maintained hypothesis, also should be identical to those generated by the preceding decompositions.

Each of these tests is applied to monthly G-7 data for the sample period 1975:1-1991:12. The $US is used as the numeraire (foreign country) currency in all cases, where the exchange rate is defined as the price of foreign currency in domestic currency units. Both consumer and wholesale prices are used to measure aggregate relative price levels across countries so that sensitivity of the results to alternative data sets can be evaluated. [7]

The results show that for no bilateral exchange rate according to the long-run neutrality criteria is long-run PPP satisfied. While permanent shocks to relative prices are typically reflected one-for-one in the nominal exchange rate, these disturbances account for a small and insignificant percentage of both nominal and real exchange rate variance. Disturbances identified to be purely transitory for relative prices, however, engender large, significant and permanent movements in nominal and real exchange rates that account for almost all of the total variance in these variables.

[6] The error-correcting form is appropriate for a maintained economic model which implies that relative prices and nominal rates cointegrate. See Engle and Granger (1987) for the source of this result. Cochrane (1992) uses a similar methodology in evaluating the source of permanent and transitory components in GNP and stock prices.

[7] In particular, this addresses criticisms of the use of consumer prices, which incorporate a high percentage of non-traded goods, in tests of PPP.

Consequently, disturbances that are only transitory for relative prices cause permanent violations of PPP. Moreover, these disturbances are never significantly reflected in relative price variation at any forecast horizon. Almost all of the variance of relative prices is accounted for by its 'own' permanent disturbance so that relative prices have an insignificant transitory component, approximating a pure random walk. Since nominal exchange rate variance is primarily attributable to transitory relative price shocks, in ten of twelve cases in the sample sources of fluctuations in relative prices and exchange rates are orthogonal.

Given the equality of nominal exchange rate and relative price effects of permanent relative price shocks under this decomposition, the decomposition that imposes this equality identifies (in ten of twelve cases) identical disturbances with identical dynamics and long-run effects. In contrast, the permanent/transitory decomposition for nominal exchange rates cannot retrieve the same disturbances as the permanent/transitory decomposition for relative prices since the two variables do not share a (single) common permanent component. The decomposition that imposes long-run PPP likewise cannot replicate the dynamics implied by the permanent/transitory relative price decomposition, and by forcing permanent real exchange rate disturbances to be zero at the infinite horizon generates transitory relative price shocks with real effects that persist beyond a five year horizon.

The results mirror the empirical observation that real and nominal exchange rates are approximately equally volatile. Importantly, they suggest that while the permanent component of prices is fully reflected in nominal exchange rates, the important source of (permanent) variation in nominal and real exchange rates is 'non-fundamental' relative to sources of fluctuations in relative goods prices. It is this component of nominal exchange rate variation that generates the permanent component in real exchange rates and so permanent disturbances to PPP.

The remainder of this paper is organized as follows. Section 1.2 briefly describes the maintained economic model, and Section 1.3 presents the mapping from this model to the empirical representation and tests. Section 1.4 describes the results of applying the test to G-7 data and Section 1.5 concludes.

1.2 The Maintained Economic Model

The strong form of purchasing power parity asserts that under conditions of free trade spatial arbitrage will ensure that the currencies of different countries command the same bundle of goods when measured in common units. The bilateral nominal exchange rate between any two currencies should therefore equal the ratio of domestic to foreign price indices pertaining to a common commodity basket. This condition is expressed in logarithms as

$$e_t = p_t - p_t^* \tag{1}$$

where e_t is the log of the domestic currency price of foreign exchange, and p_t and p_t^* are the log levels of the domestic and foreign prices.

It has long been accepted that PPP is unlikely to hold at any given point in time. Weaker forms of the doctrine account for constant wedges between bilateral nominal exchange rates and national indices of purchasing power due to impediments to free trade which are unchanging over short periods of time. This weaker form of PPP allows for constant deviations from (1) due to transportation costs, international transactions costs, policy related trade restrictions and other obstacles to trade which prohibit exact parity :

$$e_t = c + p_t - p_t^* \tag{2}$$

However, common currency prices still are assumed to be closely related and highly arbitraged. Equation (2) implies that the change in an exchange rate is determined by the change in two countries' relative price levels, or that 'relative purchasing power parity' holds :

$$\Delta e_t = \Delta p_t - \Delta p_t^* \tag{3}$$

Casual inspection of data from the floating exchange rate regime since 1974 indicate that (1), (2) and (3) have little validity as explanations of nominal exchange rate movements over short horizons. Figure 1.1 plots monthly time-series of the six G-7 bilateral currency prices, where the $U.S. is the numeraire currency, against relative consumer price indices and Figure 1.2 plots the same exchange rates against relative wholesale price indices. In both cases, movements in nominal exchange rates appear to little reflect movements in relative prices month by month. This phenomenon has been explained by many models that allow for transitory deviations from PPP, but which deliver PPP as a long-run equilibrium condition.[8]

Transitory deviations from PPP have traditionally been attributed to divergent speeds of adjustment by wages and prices relative to nominal exchange rates following permanent, country-specific shocks to money stocks and output levels which are ultimately reflected in permanent relative prices changes. If wages are fixed by long-term contracts, goods prices based on normal unit costs may adjust only slowly to these disturbances. In contrast, currency prices are determined in spot markets and can respond immediately to new disturbances to goods and asset markets. These responses are

[8]Notably, the price index used to measure wholesale prices for France is in fact an import price index and (as can be seen in the results) generates some perverse results relative to the other data series. Its dynamic behaviour is noticeably more similar to that of the exchange rate than for any other index.

argued to clear international asset markets in the short run following any disturbance that affects international interest rate differentials, and the return to alternative currency deposit holdings, but has no immediate price impact. The divergent dynamics of goods and asset prices causes nominal exchange rates to overshoot their new long-run values and induces potentially persistent, but transitory, deviations from PPP following permanent shocks to fundamentals.

Neoclassical two country, two good, two currency models deliver equilibrium (steady state) exchange rates that conform to some PPP arbitrage condition (subject to potential shifts in preferences or the marginal rate of substitution function). In these models also, steady state price levels and so exchange rates are determined by relative money stocks and outputs, 'fundamentals'. Such models must be linearized and parameterized to generate simulated dynamics out of equilibrium for exchange rates and relative prices, and few unambiguous conclusions emerge. [9]

The literature thus proposes that while (1)-(3) may not hold instantaneously, some version will hold in the absence of new disturbances and when the transitory dynamics of all previous disturbances have been fully worked out. Long-run parity is asserted. Empirically, we observe that real exchange rates which *are* deviations from (strong) PPP given by

$$r_t = e_t - (p_t - p_t^*) \tag{4}$$

diverge widely from their mean (zero) values. Figure 1.3 plots (demeaned) log real exchange rates for the G-7 countries (where prices are measured by both consumer and wholesale indices) and illustrates this point clearly. However, mere inspection of the data is insufficient to inform on whether the real rate tends to revert to mean following permanent and transitory disturbances to fundamentals. This observation is discussed in the context of testing for long-run PPP in next section.

1.3 Empirical Representations Of Disturbances To PPP

1.3.1 Univariate Representations

Relative prices and the nominal exchange rate are typically characterized as linear stochastic processes driven by underlying stochastic shocks in the fundamentals which determine macroeconomic prices and quantities. In particular, long-run PPP has been taken to imply that the real exchange rate is a covariance stationary, or a mean reverting, stochastic process with time invariant first and second moments. Any innovation in such a stationary process has finitely-lived effects which

[9] See Schlagenhauf and Wrase (1992a,1992b) for some investigation of these dynamics in models that allow for liquidity effects of monetary injections through limited participation constraints on agents' receipts of these injections.

eventually die out. Further, the long-run expected value of such a process is a time-invariant constant. [10] This is an appealing representation of long-run PPP since it implies that deviations from parity exchange rate values are finitely lived, and that ultimately the real exchange rate returns to a time-invariant constant (zero) mean value.

The condition that r be stationary is trivial if both e and $(p - p^*)$ are stationary processes. However, if fundamentals follow non-stationary processes (tastes, technology, money supplies) then long-run PPP requires cointegration of the nominal exchange rate and relative prices. Granger (1983) and Engle and Granger (1987) show that even if two variables are individually non-stationary, there may be a unique linear combination of them in which the non-stationary components cancel out and which is stationary as a consequence. In short, any permanent disturbance to relative prices originating in permanent disturbances to fundamentals must be ultimately and equally reflected in nominal exchange rates and all other disturbances transitory for both variables.

The evidence of Nelson and Plosser (1982) and numerous studies since indicates that many macroeconomic time-series can be characterized as unit root processes suggesting that underlying fundamentals may be non-stationary. Relative goods prices and nominal exchange rates may be expected to inherit this property and the perceived conventional wisdom is that this is indeed the case. [11] Long-run PPP then implies these two variables will be cointegrated with unique cointegrating vector (1,-1). The real exchange rate may be very persistent but will be stationary if this condition holds.

Typically, univariate tests of covariance stationarity of r_t take as their alternative hypothesis a stationary univariate process of a first order autoregressive moving average (ARMA) form

$$r_t = c + \alpha r_{t-1} + v_t \tag{5}$$

where c is a constant, α can take any value less than unity, and v_t is a moving average process such as

$$v_t = a(L)\epsilon_t \tag{6}$$

with a(L) a lag polynomial satisfying conditions for stationarity and invertibility. The long-run equilibrium real exchange rate is defined as the unconditional mean of this process,

$$\hat{r} = (c/(1 - \alpha)) \tag{7}$$

[10] In fact, long-run PPP requires only that the *first* unconditional moment of the real exchange rate be time invariant. Covariance stationarity is a stronger condition which has been imposed by empiricists as a condition to be satisfied in the data, but which has strong intuitive appeal as an equilibrium condition.

[11] See Meese and Singleton (1982) and Schotman (1989) on the case for non-stationarity of nominal exchange rates and Nelson and Plosser (1982) for evidence supporting non-stationarity of aggregate price indices.

Strict or short-run PPP is violated whenever the instantaneous real exchange rate does not equal this long-run value. Long-run PPP is violated whenever α is greater than or equal to unity.[12] If α equals unity, then every shock in the v_t process has a permanent effect on r through r_{t-1}. If α is less than one then each shock to the system is corrected at the rate of $(1-\alpha)$ per period and therefore eventually dies out.

For the purposes of studying the dynamic properties of real exchange rates, one can also invert the univariate ARMA process (5) to generate an infinite order moving average representation (MAR)

$$r_t = \hat{c} + d(L)\epsilon_t \tag{8}$$

where $\hat{c}$ is a constant function of c and α, and d(L) is a lag polynomial function with coefficients depending on α and a(L). The coefficients in d(L) summarize completely the dynamic behaviour of r_t in reponse to any shock ϵ_t. Once a suitable time-series representation for r_t is found, one can directly measure the persistence of deviations from PPP by studying the moving average coefficients (its univariate impulse response function).

Most empirical tests of long-run PPP have employed tests of non-stationarity (non-cointegration) of r_t based on (5). These involve a test of the null of a unit root in r_t, or α equal to unity, against the alternative that α is less than unity. Most tests of non-stationarity in exchange rate data cannot reject the null for nominal rates or relative prices. However, they also frequently fail to reject the null for the real exchange rate and conclude that long-run PPP is violated.

Yet there are three important criticisms of the univariate approach which suggest its invalidity as a method for evaluating the hypothesis of long-run PPP. First, and most generally, it is well-documented (with Monte Carlo evidence) by Schwert (1987), Blough (1988), Gregory (1991) and others, that univariate non-stationarity tests have low power to discriminate between the null and close alternative hypotheses in small samples. Lo and MacKinlay (1989) show that similar results hold for the variance-ratio tests of non-stationarity which have been applied to real exchange rates also (by Grilli and Kaminsky (1991) to evaluate PPP for the US/UK data, for example). If the hypothesis of long-run PPP is correct, tests for unit roots have low power to detect this in the data.

More specifically, Cochrane (1991) and Quah (1992) show formally that any non-stationary process has both a permanent and a transitory component, the former having arbitrarily small variance so that unit root tests have ***arbitrarily*** low power against some stationary alternatives in

[12] In fact, long-run PPP is also violated if either α or c is time-varying. This source of violation is not considered in the current paper.

small samples.[13] A meaningful test of the hypothesis of long run PPP therefore relies on being able to identify the relative *size* of the permanent component in real rates. If a real exchange rate, for which the unit root hypothesis cannot be rejected, has a permanent component with small variance, then deviations from PPP (fluctuations in real exchange rates) may be primarily transitory despite non-rejection of a univariate test for non-stationarity. Yet, as shown in (8), univariate estimation and testing allows derivation only of one, reduced form error process which may be a linear combination of multiple underlying disturbances some with permanent and some with transitory effects. Univariate time-series methods cannot identify and measure alternative sources of disturbance to PPP in the absence of additional information that imposes some structurally interpretable decomposition of variance for v_t.

The third, and related, objection to univariate methods is that they may lead to at worst misleading and at best uninformative representations of real exchange rate dynamics. Notably, Cochrane emphasizes that there exist unit root processes (with permanent components having small innovation variance) whose autocorrelation and likelihood functions are arbitrarily close to those of given stationary series. For such processes, the asymptotic distribution theory derived under the false alternative may be a better guide for statistical inference in small samples than the non-standard (correct) distribution theory derived under the assumption of non-stationarity. This calls into question the use of unit root test results as information for specifying univariate representations for exchange rate dynamics in borderline cases. Huizinga (1987) presents evidence that exchange rates lie in this 'borderline' category.

More generally, without the means to identify multiple, structurally interpretable sources of real exchange rate disturbances univariate methods have little potential to inform theory with explanations of the failure of long-run PPP.

1.3.2 Bivariate Representations

Univariate evaluations of long-run real exchange rate behaviour fail to exploit additional information that is available in multivariate systems. This extra information can be used to identify multiple

[13] In response to these criticisms, some empirical evaluations of long-run PPP have used fractional integration methods which allow for more general forms of long memory or time-dependence in real exchange rates. Diebold et al (1991), Cheung (1993) and Cheung and Lai (1993) are examples. In this work, r is represented as following a near unit root process given by $\phi(L)(1-L)^d r_t = c + v_t$ where d is allowed to be non-integer (the fractional order of integration), equal to unity under a unit root null, $\phi(L)$ is a polynomial in the lag operator satisfying conditions for stationarity and invertibility, and v_t is again a stationary (MA) error process. A stationary process is said to have long-memory if there are non-negligible autocorrelations between observations widely separated in time, yet zero effects of shocks at the infinite horizon for the level of the variable. ARFIMA modeling of real exchange rates involves estimation of d and of the associated moving average representation, and has found strong evidence to favour long-memory alternatives to non-stationary behaviour in real exchange rates.

sources of disturbance to real exchange rates, to measure their relative size in accounting for the variance of real rates, and to characterizations of exchange rate dynamics that inform theory on the role and importance of different fundamental processes. In particular, multivariate systems admit identification of both transitory and permanent components in exchange rates.

Quah (1992) shows that multivariate vector autoregressive (VAR) representations can identify both the (orthogonal) permanent and transitory components of non-stationary series. One appeal of Quah's multivariate method is that it allows for direct estimation of the two components in a simple vector-autoregressive (VAR) system specified to have meaningful structural interpretation. [14] Additionally, King and Watson (1992) suggest that such structural VAR decompositions can be used to evaluate propositions about long-run neutrality in the presence of non-stationarity in the endogenous variables of an economic model. The permanent/transitory decompositions suggested by Quah (1992) are invoked in the testing process. This methodology can be readily applied as a test of long-run PPP where, as noted above, this hypothesis translates directly into long-run neutrality propositions concerning the effects of permanent and transitory relative price disturbances for nominal exchange rates. This section shows how bivariate structural VAR's can be used to identify and measure disturbances to bilateral PPP relations and suggests how to test directly long-run PPP in this framework.

1.3.3 Representation And Identification

Models which predict long-run PPP assert that prices in each of any two economies are driven by multiple disturbances to nominal and real fundamental variables some of which are permanent and others transitory. These are the only disturbances that affect nominal exchange rates albeit with different dynamic effects. Since long-run PPP holds, permanent disturbances to prices have equal long-run effects for the nominal exchange rate, and all transitory disturbances have zero long-run effects for both variables. Consequently, both permanent and transitory disturbances are neutral for the real exchange rate in the long-run.

This suggests that bivariate structural representations of bilateral nominal exchange rates and relative prices, which allow identification of only two fundamental disturbances, are 'complete' provided that all of the underlying fundamental disturbances can be aggregated into two orthogonal representative disturbances. Given non-stationarity of nominal rates and relative prices, a bivariate system in one (aggregate) permanent relative price disturbance and one (aggregate) transitory

[14] Structural VARs have been proposed and applied by Blanchard and Quah (1989), Quah (1992) and Cochrane (1992) as alternative methods for estimating the permanent and transitory components in time series which are characterized by stochastic non-stationarity.

relative price disturbance can potentially represent such models.

Blanchard and Quah (1989) and Quah (1992), show that representations in which all permanent and all transitory disturbances are aggregated into single stochastic variables in this manner, must satisfy some regularity conditions to be valid. Specifically, two conditions must hold. First, the permanent shocks must elicit very similar dynamic responses of the two variables.[15] Second, the transitory disturbances can have different dynamic effects for the variables but must leave (nearly) unchanged the dynamic relation between them. It is assumed that these regularity conditions are met.

Assume that the vector of non-stationary economic variables, $X_t = [e_t, (p - p^*)_t]'$, is jointly, completely and fundamentally determined by a fixed set of underlying disturbances which can be aggregated into a single permanent relative price disturbance and a single transitory relative price disturbance as η_t. From Wold's Theorem, the (2×1) jointly covariance stationary stochastic vector process, ΔX_t, then has infinite (causal) vector moving average representation (MAR)

$$\Delta X_t = \Gamma(L)\eta_t \tag{9}$$

where $\Delta X_t = [\Delta e_t, \Delta(p_t - p_t^*]'$, $\Gamma(L)$ is a matrix lag polynomial summarizing the dynamics of the system and satisfying conditions for stationarity and invertibility, and η_t is a (2×1) vector of orthogonal fundamental disturbances, one of which is permanent and the other transitory for X_t, with variance- covariance matrix Σ_η. Estimation of the parameters in $\Gamma(L)$ and identification of the orthogonal innovations η_t generate a complete description of the system's dynamics.

While the MAR (9) cannot be estimated directly, it can be identified from the parameters of a reduced form parameterization under the maintained hypothesis.[16] From Engle and Granger (1987) we know that if the 2×1 vector X_t is non-stationary, or integrated of order 1 (I(1)), but the linear combination given by r_t is stationary, the covariance stationary exchange rate/relative price system can be parameterized in one of two ways. First, a vector error-correction model (VECM) given by

$$\Delta X_t = -\gamma r_{t-1} + B(L)\Delta X_{t-1} + \epsilon_t \tag{10}$$

can be estimated, where r_t is the 'error-correction term' which captures the common permanent component in e_t and $(p - p^*)_t$. Its inclusion restores the spectral density of the model to full rank (accounts for the singularity in $\Gamma(1)$ due to the presence of this common permanent component).[17] These cointegrated representations are correct under the maintained hypothesis.

[15] This condition appears to be satisfied in the impulse response functions estimated below.

[16] Direct estimation of the system is possible if there exist strictly exogenous variables which can be used as instruments allowing identification of any non-zero contemporaneous multipliers.

[17] See Yoo (1985).

This parameterization can be inverted and transformed to produce a reduced form MAR of the form

$$\Delta X_t = C(L)\epsilon_t \tag{11}$$

where C(0) = I and the variance-covariance matrix of ϵ_t is given by Σ_ϵ. From (9) and (11)

$$\Gamma(L)\eta_t = C(L)\epsilon_t \tag{12}$$

and since C(0) = I the structural innovations are given by

$$\eta_t = \Gamma(0)^{-1}\epsilon_t \tag{13}$$

and the dynamic multipliers by

$$\Gamma(L) = C(L)\Gamma(0) \tag{14}$$

Hence, the structural innovations and parameters can all be identified given knowledge of $\Gamma(0)$.

From (13), the covariance condition

$$\Sigma_\epsilon = \Gamma(0)\Sigma_\eta\Gamma(0)\prime \tag{15}$$

provides 3 restrictions which must be satisfied by the elements of $\Gamma(0)$.[18] However, there are 4 distinct elements to be estimated in $\Gamma(0)$, and so multiple representations of (9) admissable from (11) conditional on the fourth identifying restriction imposed, each of which allows for the contemporaneous joint determination of the elements of X_t by orthogonal disturbances.

Notably, the hypothesis of long-run PPP assumed in (9) involves two restrictions on the elements of $\Gamma(1) = \sum_{i=0}^{\infty}\Gamma_i$, the long-run multiplier matrix for the two disturbances.[19] These are

$$\begin{aligned}
\Gamma(1)_{11} &= \Gamma(1)_{21} && (16)\\
&\neq 0 && (17)\\
\Gamma(1)_{12} &= \Gamma(1)_{22} && (18)\\
&= 0 && (19)
\end{aligned}$$

where the first disturbance in the system is (arbitrarily) identified as the permanent relative price shock and the second as the transitory relative price shock. These two restrictions overidentify the

[18]In fact, Σ_η is normalized to be the identity matrix and the diagonal elements of $\Gamma(0)$ estimated as the impact multipliers.

[19]$\Gamma(1)$ represents the cumulative impact of each disturbance on the elements of ΔX_t. (If X_t is a covariance stationary vector, then these long-run effects are zero.) If X_t is non-stationary in levels and the VAR is thus specified in first differences of X_t, $\Gamma(1)$ reflects both the cumulative impact of a given disturbance on the first difference of the variable and the infinite horizon effect on the *level* of the variable.

model, but imposition of either one in some form should, under the maintained model, retrieve the structural representation of interest. One of these constraints can therefore be imposed as a restriction on the elements of $C(1)\Gamma(0) = \Gamma(1)$.

An alternative representation, which directly imposes long-run PPP, is a reduced form cointegrated VAR in $Y = [\Delta(p-p^*)_t, r_t]'$ which is estimated as

$$Y_t = B(L)Y_{t-1} + \epsilon_t \tag{20}$$

In this instance the same identification problem arises. Now, however, a single restriction will suffice to identify the maintained model since long-run PPP is embodied in the specification through the inclusion of r_t as a dependent variable. Specifically, imposing that the long-run effect of one disturbance for $(p-p^*)_t$ is zero will retrieve (9) directly. Such a zero restriction on $\Gamma(1)$ implies a representation for η_t in terms of permanent and transitory disturbances for relative prices a la Blanchard and Quah (1989).

For both parameterizations, the underlying structural model can be retrieved in the form of interest (as a description of the levels behaviour of exchange rates and prices following alternative disturbances) as

$$X_t = \Gamma(L)/(1-L)\eta_t \tag{21}$$

by appropriate transformation of the estimated parameters. The levels behaviour of the real exchange rate is directly estimated from the second parameterization and can be derived by appropriate transformations from the first.

1.3.4 Tests Of Long-Run PPP

Following King and Watson (1992), two tests of long-run PPP are proposed which use the two parameterizations of (9) described above.

First, three alternative long-run restrictions are imposed on the reduced form MAR (11) and the overidentifying restrictions used to evaluate the validity of the joint hypotheses (16) and (18). These restrictions are

$$\Gamma(1)_{22} = 0 \tag{22}$$

$$\Gamma(1)_{12} = 0 \tag{23}$$

$$\Gamma(1)_{11} = \Gamma_{21} \tag{24}$$

(22) identifies the second disturbance in the system as purely transitory for $(p - p^*)_t$.[20] The resulting structural model is referred to as Model (1). Under the maintained hypothesis, this restriction generates a representation in which the following (necessary) conditions are observed:

$$\Gamma(1)_{21} = \Gamma(1)_{11} \tag{25}$$

$$\Gamma(1)_{12} = 0 \tag{26}$$

Consequently, both the first (permanent relative price) disturbance and the transitory relative price disturbance are neutral for the real exchange rate at the infinite horizon.

(23) identifies the second disturbance in the system as purely transitory for e_t. The resulting structural model is referred to as Model (2). Under the maintained hypothesis, this restriction generates a representation in which the following (necessary) conditions are observed:

$$\Gamma(1)_{21} = \Gamma(1)_{11} \tag{27}$$

$$\Gamma(1)_{22} = 0 \tag{28}$$

Consequently, both disturbances are neutral for the real exchange rate at the infinite horizon. The identified system should be identical to that identified by Model (1).

(24) identifies the first disturbance as having equal long-run effects for e_t and $(p - p^*)_t$. The resulting structural model is referred to as Model (3). Under the maintained hypothesis, this restriction generates a representation in which the following (necessary) condition is observed:

$$\Gamma(1)_{12} = \Gamma(1)_{22} \tag{29}$$

Again, both disturbances are neutral for the real exchange rate at the infinite horizon and the identified system should be identical to that identified for Models 1 and 2. Both the long-run multiplier matrix and the parameters in $\Gamma(L)/(1 - L)$ are inspected for evidence of significant deviations from long-run PPP. [21] However, even if one of the conditions required for the system to satisfy long-run PPP according to the preceding criteria fails, the forecast error variance decompositions could indicate that the implied source of the PPP deviation accounts for a negligible fraction of real exchange rate variance. This trivariate of statistics therefore are used together to evaluate the hypothesis.

[20]The choice of ordering for the identified disturbances involves a normalization; the point estimates are unique up to a column sign change. Notably, there may be differences across choice of ordering in small sample inference due to sampling error. In general, the inference based on simulated standard errors computed in this paper is robust to such changes in ordering.

[21]In all tests, statistical inference is based on empirical distributions computed by Monte Carlo integration using 2500 replications and based on standard distributional assumptions for the reduced form VECM parameters.

The second test of the long-run PPP hypothesis involves use of the identified system (21), which will be referred to as Model (4). In this case, there is no unique set of overidentifying restrictions supplied by theory which can be used to evaluate the model's performance. Since long-run PPP is directly imposed on the system, a test of this hypothesis involves evaluating the compatibility of the resulting dynamics of the system to those of economic models that predict that long-run PPP will hold. These dynamics, moreover, should be consistent with those generated by Models (1)-(3). Finally, this model informs theory on the dynamics that should be generated by any theoretical structure that has long-run PPP as an equilibrium condition.

1.4 Results

All estimation is conducted for the sample period 1975:1-1991:12 (except for the Italian data which were available only to 1989:12) for the G-7 countries Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. For data sources and definitions see Table 1.1. The nominal exchange rate is defined as the (log of) the price of one U.S. dollar in units of domestic currency. Relative prices are defined as the log of the relative consumer (wholesale) price index of the domestic price index minus the log of the relevant price index in the U.S. Each series demeaned prior to estimation. Two price indices were used in order to assess robustness of the results to the use of alternative data series, where one of these (the consumer price index) is commonly attributed with partial responsibility for rejections of long-run PPP in the data due to its including a relatively large component of non-tradeable goods' prices.

1.4.1 Reduced Form Estimation

For each country, two VECM'S and two VAR's (each with four lags included of each endogenous variable)[22] are estimated where, in the second VAR relative consumer prices are replaced by relative wholesale prices. The coefficients on the lagged error-correction term (lagged value of the real exchange rate) in the VECMs are shown in Tables 1.2a and 1.2b. These indicate that the lagged level (error-correction) variable appears to play the appropriate 'correcting' role for the nominal exchange rate; a positive deviation from PPP (due either to a positive shock to nominal rates or a negative relative price disturbance) causes a negative nominal exchange rate response in the following period. Furthermore, relative prices rise in the period following a positive PPP disturbance. There therefore appears to be a tendency for all currencies and relative prices to act to eliminate

[22] This lag length is selected primarily by standard information criteria, and appropriate for most data sets. Consistency of lag length across different country data sets was the deciding criterion in marginal cases.

short-run 'disequilibria'. However, in few cases are the coefficients on the error-correction term significant, suggesting weak support for the error-correcting specification.

1.4.2 Structural Model Estimation

The reduced form VECM's and VAR's are inverted and the structural moving average Models (1)-(4) estimated using the identification procedures described above. [23]

1.4.3 Long-Run Multiplier Estimates

Estimated long-run multiplier matrices for each country (and price index) are shown in Table 1.3. (These are based on the response of each variable to alternative innovations after 204 months.) This provides information directly on the validity of long-run PPP in this data for Models (1)-(3). In many cases the estimates are significant, however, in some the estimates are highly imprecise which is inevitable in direct estimation of long-run responses. Consequently, the impulse response functions (elements of $\Gamma(L)$) are also reported in the following section for a *one year* horizon, and these provide additional inference.

For Canada, the results for Model (1) indicate that while permanent relative price disturbances have an approximately equal effect on nominal exchange rates and relative prices, there is a large and significant permanent effect for nominal exchange rates of disturbances that only transitorily move relative prices. The size and significance of this effect is independent of which price index is used to identify relative price shocks. The results for Model (3) reflect those for Model (1). The permanent relative price shock identified in Model (1) appears to be exactly that identified in Model (3) as the disturbance with equal long-run nominal exchange rate and relative price effects. The long-run multiplier estimates for Model (2) are consistent with the finding of permanent nominal exchange rate effects of transitory price disturbances and comparatively small nominal rate long-run effects of *permanent* relative price disturbances. The relative price infinite horizon response to permanent exchange rate shocks is barely significant, while its response to transitory exchange rate shocks is highly significant and is close in value to the relative price response to its own permanent shock in Model (1). The permanent exchange rate component generated by Model (2) is apparently not identifiable with the permanent relative price disturbance generated by Model (1).

In the German data, the equality of relative price and nominal exchange rate responses to permanent price shocks in Model (1) is subject to more uncertainty but remains consistent with

[23] All identification is computed by solving the implied nonlinear system of equations given by (16) and the relevant linear restrictions on the elements of $C(1)\Gamma(0)$ in the GAUSS NLSYS package using the default non-linear solution algorithm and program settings.

the Canadian results. The German VECM's based on alternative price indices generate a similar size for the 'excess' permanent nominal exchange rate component. Again, Model (3) reflects the results of Model (1) and Model (2) implies a significant permanent relative price response only following disturbances identified as being transitory for the nominal exchange rate. A remarkably similar pattern of infinite horizon responses emerges in the Italian and UK data.

The French and Japanese cases warrant further comment. In these cases, the additional inference afforded by the impulse response analysis is especially valuable in assessing the long-run effects of alternative disturbances for the real exchange rate. For both countries, the nominal exchange rate response to permanent relative price disturbances in Model (1) is imprecisely estimated and insignificantly different from zero when consumer prices are used. For France, the relative price response is also imprecisely estimated in this instance. However, a significant 'excess' permanent nominal exchange rate component is observed when both consumer and wholesale price measures of relative prices are used for both countries.

In general, these results show that there exist large permanent nominal exchange rate movements which occur independently of permanent relative price movements and despite the approximately equal effect of the latter for nominal rates predicted by models of long-run PPP. Consequently, the results for Models (1) and (3) coincide for ten of the twelve cases studied , and the results of Model (1) and Model (2) are significantly different. Given this indication of rejection of long-run PPP, the remaining results reported focus on Model (1) and Model (4) in further evaluating the hypothesis.[24]

1.4.4 Impulse Response Functions

The impulse response functions provide information regarding the behaviour of nominal exchange rates, relative prices and the real exchange rate for one year following a disturbance of one standard deviation (unity) in an orthogonal innovation. The results for Model (1) are shown in Figures 1.4-1.9 for consumer price indices and in Figures 1.4(wp)-1.9(wp) for wholesale price indices. The Canadian results indicate negligible differences in nominal exchange rate, relative price and real exchange rate dynamics following permanent and transitory relative price disturbances when alternative price indices are employed. In both cases, the long-run effects are complete for the levels of each variable by the twelve month horizon. The permanent price disturbance raises relative prices and the nominal exchange rate permanently by equal amounts and has no significant real exchange rate impact at *any* lag since the nominal rate and price dynamics are insignificantly different from each

[24]Results for Models (2) and (3) are available from the author upon request.

other. The transitory price disturbance accounts for no significant movement in relative prices at any lag but engenders a large, significant nominal exchange rate response at all lags. This suggests that relative prices follow a pure random walk (have an insignificant transitory component) and that if long-run PPP fails in the Canadian data it is due to the response of the nominal exchange rate to disturbances which have no effect for relative prices, or 'fundamentals' as they are measured here.[25]

The results for France are similar in the latter respect. Transitory relative price disturbances have no significant effect for relative prices at any lag, but a large, positive and increasing effect for the nominal exchange rate. This is true for both wholesale and consumer price indices. There are, however, some differences in responses to the permanent price disturbance compared to the Canadian model, and conditional on the definition of prices used. Again, this disturbance permanently raises both relative prices and the nominal exchange rate but there is a small, significant effect for the real exchange rate. When consumer prices are used, while the relative price and nominal rate respsonses are indistinguishable at low lags they diverge at longer lags with the nominal exchange rate impact exceeding that for relative prices. This generates a significant and positive effect for the real exchange rate after six months although this effect is estimated with a large standard error even at this horizon. When wholesale prices are used, the real exchange rate is significantly and *negatively* affected by the permanent price disturbance at all lags, although again this effect is estimated somewhat imprecisely. In this case, the relative price response exceeds that of the nominal rate at all lags. [26]

The German data reflects the Canadian results. There are no significant differences in dynamics that depend on which price index is used and in both cases there are insignificant real exchange rate effects at all lags following a permanent relative price shock. Again, the real rate is permanently raised at all horizons after a transitory price disturbance which has no significant effect for relative prices but a large, significant positive impact for the nominal exchange rate. The Italian models and the Japanese consumer price index case also reproduce these results in Figures 1.7, 1.7(wp), and in Figure 1.8. The use of wholesale price indices in the Japanese case, however, generates a significant and positive real exchange rate response following a permanent price disturbance. Yet, disturbances to PPP due to the transitory price shock retain the properties exhibited in all previous cases.

[25]The impulse response functions for Model (2) also suggest that relative prices contain no significant transitory component; there are significant permanent relative price responses following both permanent and transitory exchange rate disturbances.

[26]The results' sensitivity to the use of alternative price indices may be attributable to the use of an imported materials price index to proxy for wholesale prices in the absence of an alternative series being available.

Finally, the results for the UK/US system are shown in Figures 1.9 and 1.9(wp). The dynamic effects of the transitory relative price disturbance reflect all previous results. There are permanent components in nominal and real exchange rates that are never reflected in relative prices. Similarly, the permanent price shock generates no significant real exchange rate response at any lag, corroborating the earlier results concerning the long-run neutrality of the permanent price component for most currency prices.

Model (4) produces impulse responses (those for relative prices and the real exchange rate are shown in Figures 1.10-1.15 and in Figures 1.10(wp)-1.15(wp)) which show how the dynamics generated from a representation which imposes long-run PPP differ from those in Model (1). The impulses are plotted to a five year horizon at which not all disturbances, which are by assumption transitory for the real exchange rate, have dissipated.

Clearly, there are significant differences in the estimated parameters of the impulse response functions from Models (1) and (4) for all countries and both prices indices at most horizons following transitory relative price disturbances. Imposing long-run PPP on a relative price permanent/transitory decomposition requires that *both* disturbances be neutral for the real exchange rate at the infinite (204 month) horizon. From Model (1), we know that Model (4) is misspecified and this reflects in the differences across the two Models. In particular, the long-run PPP model identifies 'transitory' relative price disturbances with effects for the real exchange rate that die out more gradually than those that are identified as being permanent for relative prices.

This is due, in the case of the consumer price models, to a large and significant nominal exchange rate response to the transitory shock which, while restricted to have no real effects at the infinite horizon, is clearly highly persistent. The 'excess' permanent nominal exchange rate component in Model (1) is forced to satisfy an infinite horizon zero restriction in Model (4) which generates this result. This is true for all countries and both measures of prices. The permanent relative price disturbance is neutral for the real exchange rate at all lags for the Canadian and UK models, but has significant real effects to at least a one year horizon for the remaining cases. Model (4) apparently induces these prolonged real effects of the permanent relative price disturbance by forcing all permanent real effects to be zero in this decomposition of variance.

In the wholesale price models, permanent relative price shocks also have prolonged real effects in the Canadian and German data, while the same protracted transitory price shock is observed as in the consumer price models. Notably, there are significant *negative* relative price responses to this disturbance while the implied nominal exchange rate response is positive. This pattern of responses is difficult to reconcile with the implications of standard models of exchange rate dynamics.

1.4.5 Forecast Error Variance Decompositions

The preceding results show that there exist large permanent nominal exchange rate disturbances with no significant price effects that force most disturbances to long-run PPP. However, the relative importance of these long-run PPP disturbances can only be ascertained by evaluating the percentage of the total real exchange rate variance accounted for by them at any given forecast horizon. Forecast error variance decompositions are therefore constructed for each country and price index for Models (1) and (4) which show the percentage of the total forecast error variance accounted for by each disturbance at various forecast horizons. The results for Model (1) are shown in Tables 1.4a and 1.4b.

The results for Canada indicate that the permanent price disturbance accounts for a small and insignificant fraction of the total variance in the real exchange rate although it can explain almost all of the variance in relative prices. Further, almost all of the variance in nominal exchange rates is accounted for by the transitory price shock, so that the percentage forecast error variance of both real and nominal exchange rates explained by this disturbance are very similar. These observations suggest that while relative prices are approximately a pure random walk with respect to some permanent shock(s), real exchange rate variation is largely due to sources of 'non-fundamental' permanent nominal exchange rate movements not reflected in relative prices. Moreover, the fact that long and short-run neutrality of permanent relative price disturbances holds in the data is typically irrelevant for real exchange rate behaviour. Finally, given these results, one would expect to observe the variation in real and nominal exchange rates to be very similar in the data and for nominal exchange rates and relative prices to look more alike than real exchange rates and relative prices.

These results are mirrored in the reports for the remaining five countries with few exceptions. In the French consumer price index (Model (1)) case, long-run PPP violations attributable to the permanent price disturbance which were observed in the impulse response functions account for about one quarter of all violations. However, in the (perverse) wholesale price case this source of long-run PPP deviations accounts for an insignificant percentage of real exchange rate variance. Consequently, the 'excess' permanent nominal exchange rate variation retains dominance in generating permanent real exchange rate movements in both cases. In the Italian wholesale price data, nominal exchange rate variation is more strongly associated with the permanent price disturbance than is typically the case, however this has no impact on the relative importance of transitory price disturbances for purchasing power parity deviations in the long-run which is negligible.

While the results for Japan in which consumer prices are used reflect the Canadian case, the use of wholesale prices introduces a significant change. Here, permanent relative price shocks can account for almost one half of all real exchange rate variation, and are especially important at short horizons. Since the impulse responses indicate the existence of permanent real exchange rate shocks due to this disturbance when wholesale prices are used, deviations from long-run PPP occur with approximately equal frequency due to permanent and transitory price disturbances here.

Overall, the results from Model (1) therefore indicate that in ten of twelve cases there are significant permanent disturbances to PPP that are almost entirely attributable to permanent nominal exchange rate shocks which are never reflected in relative prices.

The forecast error variance decompositions from Model (4) which imposes long-run PPP therefore look very different to those for Model (1) in several cases. At the (relatively short) forecast horizons considered, relative price variance is accounted for less by the disturbance identified to be permanent than in Model (1), and real exchange rate variance is accounted for more by this disturbance although in most cases the fraction of real exchange rate variance attributable to this shock is insignificant over all but very short horizons. Notably, when wholesale prices are used in the decompositions significant differences are observed over these (short) horizons in the Canadian and German models. Here, most real exchange rate forecast variance is accounted for by the permanent relative price disturbance. While this sensitivity of the results to alternative price indices is surprising, it remains true that in ten of twelve cases an insignificant fraction of real exchange rate variation is caused by permanent relative price shocks.

1.5 Conclusion

The results indicate that in ten of the twelve cases studied, there are deviations from PPP at all horizons that are almost entirely attributable to disturbances that have permanent nominal exchange rate effects but which are never reflected in relative prices. This is despite the fact that permanent relative price disturbances are typically reflected one-for-one in nominal exchange rates as predicted by models that deliver long-run PPP as an equilibrium condition. There is a large and significant permanent component in real exchange rates.

In fact, permanent relative price disturbances account for a insignificant percentage of nominal and real exchange rate variance at most forecast horizons but account for approximately 100% of the variance of relative prices. This suggests that there are important sources of (permanent) nominal and real exchange rate movements that are never captured in the 'fundamentals' proposed by many theoretical representations as long-run determinants of exchange rates. Notably, imposing long-run PPP on the data induces decompositions of variance that generate dynamics which are difficult to reconcile with the implications of standard models of exchange rate determination, and transitory shocks with extraordinarily long-lived real exchange rate effects.

The estimated (unrestricted) decompositions are consistent with the empirical observation that nominal and real exchange rates are approximately equally volatile and that neither variable appears to be closely related to relative price movements. In fact, sources of fluctuations in relative prices and exchange rates in ten of twelve cases are orthogonal. Furthermore, in these cases, whether consumer or wholesale prices are used to construct a relative price variable is irrelevant for the main results, suggesting that previous criticisms of the use of consumer prices for evaluating propositions about PPP may be unfounded.

Clearly, further empirical analysis is needed to uncover the source of the 'excess' permanent nominal and real exchange rate component identified here. Finer decompositions of exchange rate variance would be required to achieve this, and this is left to future work.

Table 1.1: Data Sources

All series are monthly, deterministically seasonally adjusted, logarithmically transformed and demeaned prior to estimation.

- consumer price indices are averaged data from the Citibase database, available from 1974:1-1991:12 for all countries.
- wholesale price indices are averaged data from the International Monetary Fund's International Financial Statistics database, available from 1974:1-1991:12 for all but the Italian series for which the sample is 1974:1-1989:12.
    1. for Canada this index is the aggregate industry selling price index
    2. for France this index is the price of imported materials index
    3. for Germany this index is the wholesale price index for industrials
    4. for Italy this index is a general wholesale price index
    5. for Japan this index is a general wholesale price index
    6. for the UK this index is the industrial output price index
    7. for the US this index is the price index of industrial output
- nominal exchange rates are averages of daily noon spot rates from the Citibase database, available 1974:1-1991:12 for all series

Table 1.2: Reduced Form VECM Results

Table 1.2a: Error Correction Terms (CPI's)

Country	Equation	Estimated Coefficient	t-statistic
Canada	Δe_t	-0.011	-1.222
	$\Delta(p-p^*)_t$	0.002	0.468
France	Δe_t	-0.026	-1.909
	$\Delta(p-p^*)_t$	0.002	1.026
Germany	Δe_t	-0.016	-1.499
	$\Delta(p-p^*)_t$	0.002	1.146
Italy	Δe_t	-0.015	-1.413
	$\Delta(p-p^*)_t$	0.005	1.344
Japan	Δe_t	-0.015	-1.365
	$\Delta(p-p^*)_t$	0.004	1.720
UK	Δe_t	-0.021	-1.767
	$\Delta(p-p^*)_t$	0.002	0.688

Table 1.2b: Error-Correction Terms (WPI's)

Country	Equation	Estimated Coefficient	t-statistic
Canada	Δe_t	-0.000	-0.025
	$\Delta(p-p^*)_t$	0.019	2.802^{**}
France	Δe_t	-0.013	-1.018
	$\Delta(p-p^*)_t$	0.002	0.175
Germany	Δe_t	-0.013	-0.993
	$\Delta(p-p^*)_t$	0.002	2.467^{*}
Italy	Δe_t	-0.011	-0.843
	$\Delta(p-p^*)_t$	0.005	0.821
Japan	Δe_t	-0.021	-1.531
	$\Delta(p-p^*)_t$	0.000	0.015
UK	Δe_t	-0.014	-1.141
	$\Delta(p-p^*)_t$	0.006	1.834

Table 1.3: Estimated Long-Run Multipliers

Table 1.3a: Model (1) Estimates (CPI's)

Country	Variable	Permanent (p-p*) Shock	Transitory (p-p*) Shock
Canada	Δe_t	0.0067	0.0138
		(0.0058)	(0.0033)
	$\Delta(p - p^*)_t$	0.0066	0.0
		(0.0019)	0.0
France	Δe_t	0.0466	0.0523
		(38.495)	(0.0188)
	$\Delta(p - p^*)_t$	0.0094	0.0
		(4.3218)	0.0
Germany	Δe_t	0.0221	0.0459
		(0.0468)	(0.0133)
	$\Delta(p - p^*)_t$	0.0114	0.0
		(0.0129)	0.0
Italy	Δe_t	0.0235	0.0461
		(0.0268)	(0.020)
	$\Delta(p - p^*)_t$	0.0201	0.0
		(0.0073)	0.0
Japan	Δe_t	-0.0032	0.0565
		(0.0329)	(0.0197)
	$\Delta(p - p^*)_t$	0.0090	0.0
		(0.0011)	0.0
UK	Δe_t	0.0190	0.0480
		(0.0356)	(0.0157)
	$\Delta(p - p^*)_t$	0.0174	0.0
		(0.0087)	0.0

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.3: Estimated Long-Run Multipliers

Table 1.3b: Model (1) Estimates (WPI's)

Country	**Variable**	**Permanent (p-p*) Shock**	**Transitory (p-p*) Shock**
Canada	Δe_t	0.0054	0.0131
		(0.0049)	(0.0034)
	$\Delta(p - p^*)_t$	0.0056	0.0
		(0.0011)	0.0
France	Δe_t	0.0297	0.0383
		(0.0192)	(0.0124)
	$\Delta(p - p^*)_t$	0.0466	0.0
		(0.0141)	0.0
Germany	Δe_t	0.0165	0.0456
		(0.0043)	(0.0195)
	$\Delta(p - p^*)_t$	0.0087	0.0
		(0.0046)	0.0
Italy	Δe_t	0.0374	0.0371
		(0.0357)	(0.0108)
	$\Delta(p - p^*)_t$	0.0246	0.0
		(0.0129)	0.0
Japan	Δe_t	0.0458	0.0374
		(0.0506)	(0.0149)
	$\Delta(p - p^*)_t$	0.0164	0.0
		(0.0120)	0.0
UK	Δe_t	0.0149	0.0467
		(3.9171)	(0.0162)
	$\Delta(p - p^*)_t$	0.0169	0.0
		(0.7075)	0.0

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.3: Estimated Long-Run Multipliers

Table 1.3c: Model (2) Estimates (CPI's)

Country	Variable	Permanent e Shock	Transitory e Shock
Canada	Δe_t	0.0157	0.0
		(0.0052)	0.0
	$\Delta(p - p^*)_t$	0.0029	0.0061
		(0.0029)	(0.0013)
France	Δe_t	0.0700	0.0
		(814.79)	0.0
	$\Delta(p - p^*)_t$	0.0063	0.0070
		(58.761)	(0.0025)
Germany	Δe_t	0.0510	0.0
		(0.0371)	0.0
	$\Delta(p - p^*)_t$	0.0049	0.0103
		(0.0082)	(0.0027)
Italy	Δe_t	0.0516	0.0
		(0.0101)	0.0
	$\Delta(p - p^*)_t$	0.0091	0.0178
		(0.0101)	(0.0046)
Japan	Δe_t	0.0564	0.0
		(0.0331)	0.0
	$\Delta(p - p^*)_t$	-0.0005	0.0090
		(0.0046)	(0.0021)
UK	Δe_t	0.0518	0.0
		(0.0383)	0.0
	$\Delta(p - p^*)_t$	0.0064	0.0160
		(0.0140)	(0.0043)

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.3: Estimated Long-Run Multipliers

Table 1.3d: Model (2) Estimates (WPI's)

Country	Variable	Permanent e Shock	Transitory e Shock
Canada	Δe_t	0.0141	0.0
		(0.0043)	0.0
	$\Delta(p - p^*)_t$	0.0022	0.0052
		(0.0017)	(0.0008)
France	Δe_t	0.0485	0.0
		(0.0172)	0.0
	$\Delta(p - p^*)_t$	0.0286	0.0369
		(0.0170)	(0.0106)
Germany	Δe_t	0.0514	0.0
		(0.0319)	0.0
	$\Delta(p - p^*)_t$	0.0028	0.0083
		(0.0039)	(0.0014)
Italy	Δe_t	0.0526	0.0
		(0.0356)	0.0
	$\Delta(p - p^*)_t$	0.0175	0.0173
		(0.0167)	(0.0039)
Japan	Δe_t	0.0591	0.0
		(0.1146)	0.0
	$\Delta(p - p^*)_t$	0.0127	0.0104
		(0.0311)	(0.0070)
UK	Δe_t	0.0489	0.0
		(0.3420)	0.0
	$\Delta(p - p^*)_t$	0.0051	0.0161
		(0.0594)	(0.0035)

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.3: Estimated Long-Run Multipliers

Table 1.3e: Model (3) Estimates (CPI's)

Country	Variable	Common Shock	Second Shock
Canada	Δe_t	0.0066	0.0139
		(0.0017)	(0.0052)
	$\Delta(p - p^*)_t$	0.0066	0.0001
		(0.0017)	(0.0026)
France	Δe_t	0.0077	0.0697
		(0.0024)	(4.7714)
	$\Delta(p - p^*)_t$	0.0077	0.0055
		(0.0024)	(0.6291)
Germany	Δe_t	0.0111	0.0498
		(0.0038)	(0.0437)
	$\Delta(p - p^*)_t$	0.0111	0.0026
		(0.0038)	(0.0125)
Italy	Δe_t	0.0199	0.0475
		(0.0055)	(0.0561)
	$\Delta(p - p^*)_t$	0.0199	0.0015
		(0.0055)	(0.0242)
Japan	Δe_t	0.0088	0.0557
		(0.0021)	(0.0266)
	$\Delta(p - p^*)_t$	0.0088	-0.0019
		(0.0021)	(0.0041)
UK	Δe_t	0.0174	0.0488
		(0.0051)	(0.0262)
	$\Delta(p - p^*)_t$	0.0174	0.0006
		(0.0051)	(0.0090)

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.3: Estimated Long-Run Multipliers

Table 1.3f: Model (3) Estimates (WPI's)

Country	Variable	Commmon Shock	Second Shock
Canada	Δe_t	0.0057	0.0139
		(0.0009)	(0.0052)
	$\Delta(p - p^*)_t$	0.0057	-0.0001
		(0.0009)	(0.0017)
France	Δe_t	0.0427	0.0130
		(0.0432)	(0.0043)
	$\Delta(p - p^*)_t$	0.0427	-0.0189
		(0.0432)	(0.0279)
Germany	Δe_t	0.0087	0.0506
		(0.0016)	(0.1112)
	$\Delta(p - p^*)_t$	0.0087	0.0014
		(0.0016)	(0.0082)
Italy	Δe_t	0.0232	0.0472
		(0.0082)	(0.1989)
	$\Delta(p - p^*)_t$	0.0232	0.0080
		(0.0082)	(0.0847)
Japan	Δe_t	0.0129	0.0577
		(0.0134)	(0.0738)
	$\Delta(p - p^*)_t$	0.0129	0.0101
		(0.0134)	(0.0149)
UK	Δe_t	0.0168	0.0459
		(0.0042)	(0.0234)
	$\Delta(p - p^*)_t$	0.0168	-0.0007
		(0.0042)	(0.0072)

Each element reports the response of the **Variable** to each alternative **Shock** at the infinite horizon (204 months), which is also the cumulative impact on the level of each **Variable**. Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Table 1.4: Forecast Error Variance Decompositions

Table 1.4a: Model (1) Estimates (CPI's)

Percentage Forecast Error Due To Permanent Relative Price Shock

Country	Variable	1 month	6 months	12 months	24 months
Canada	e_t	4.24	8.36	12.66	16.00
		(9.42)	(11.87)	(14.30)	(16.37)
	$(p - p^*)_t$	93.81	97.20	98.83	99.52
		(10.14)	(4.85)	(2.12)	(0.82)
	$(e - p + p^*)_t$	2.19	1.04	0.52	0.24
		(8.18)	(7.47)	(7.98)	(9.12)
France	e_t	4.84	14.00	25.55	35.51
		(13.38)	(17.39)	(20.88)	(23.50)
	$(p - p^*)_t$	93.13	94.88	97.64	99.10
		(14.37)	(9.80)	(5.32)	(1.70)
	$(e - p + p^*)_t$	0.71	5.58	14.70	24.21
		(10.34)	(13.64)	(18.18)	(22.31)
Germany	e_t	5.93	7.64	11.49	14.99
		(12.17)	(13.17)	(15.94)	(18.77)
	$(p - p^*)_t$	96.83	98.49	99.38	99.77
		(10.17)	(5.31)	(2.53)	(0.90)
	$(e - p + p^*)_t$	0.22	1.27	2.42	3.65
		(7.95)	(9.15)	(11.51)	(14.41)
Italy	e_t	1.59	13.43	16.53	18.68
		(10.98)	(16.54)	(18.00)	(19.47)
	$(p - p^*)_t$	99.08	99.90	99.96	99.98
		(9.90)	(5.16)	(2.69)	(1.1)
	$(e - p + p^*)_t$	3.69	0.53	0.45	0.49
		(11.97)	(9.77)	(11.04)	(12.65)
Japan	e_t	0.02	0.36	0.36	0.34
		(10.56)	(11.50)	(12.25)	(13.09)
	$(p - p^*)_t$	99.40	99.56	99.80	99.91
		(10.70)	(6.58)	(3.70)	(1.62)
	$(e - p + p^*)_t$	6.25	5.11	4.83	4.63
		(15.03)	(14.62)	(14.95)	(15.46)
UK	e_t	2.88	5.15	8.07	10.75
		(11.31)	(12.85)	(14.98)	(17.18)
	$(p - p^*)_t$	95.06	97.70	99.04	99.62
		(12.21)	(6.85)	(3.35)	(1.26)
	$(e - p + p^*)_t$	1.33	0.35	0.15	0.11
		(10.32)	(10.35)	(10.63)	(12.16)

Table 1.4: Forecast Error Variance Decompositions

Table 1.4b: Model (1) Estimates (WPI's)

Percentage Forecast Error Due To Permanent Relative Price Shock

Country	Variable	1 month	6 months	12 months	24 months
Canada	e_t	16.17	13.84	14.32	14.52
		(15.43)	(14.47)	(15.15)	(15.57)
	$(p - p^*)_t$	95.54	99.19	99.60	99.80
		(9.92)	(3.55)	(1.73)	(0.29)
	$(e - p + p^*)_t$	0.57	1.22	0.58	0.29
		(7.87)	(8.41)	(8.40)	(8.74)
France	e_t	43.11	48.50	44.74	41.02
		(22.98)	(21.25)	(20.41)	(20.51)
	$(p - p^*)_t$	99.17	99.77	99.89	99.95
		(10.01)	(5.68)	(3.16)	(1.41)
	$(e - p + p^*)_t$	26.22	18.25	17.14	16.68
		(20.80)	(18.36)	(18.41)	(18.88)
Germany	e_t	11.98	8.15	9.26	9.83
		(16.73)	(14.93)	(16.11)	(16.94)
	$(p - p^*)_t$	97.61	99.39	99.72	99.87
		(11.34)	(6.18)	(3.53)	(1.84)
	$(e - p + p^*)_t$	1.59	0.85	1.57	2.05
		(10.85)	(10.59)	(12.00)	(13.23)
Italy	e_t	43.59	44.58	47.19	48.97
		(21.75)	(20.61)	(20.80)	(21.45)
	$(p - p^*)_t$	90.49	97.33	98.95	99.58
		(14.28)	(6.54)	(3.01)	(1.13)
	$(e - p + p^*)_t$	7.95	7.92	8.97	9.83
		(13.79)	(14.44)	(16.05)	(17.79)
Japan	e_t	77.36	63.93	61.75	60.75
		(17.44)	(18.05)	(18.29)	(18.78)
	$(p - p^*)_t$	81.09	94.71	97.80	99.06
		(16.94)	(7.70)	(3.57)	(1.40)
	$(e - p + p^*)_t$	51.61	37.25	37.11	37.70
		(20.35)	(19.64)	(20.48)	(21.40)
UK	e_t	2.14	1.86	4.64	7.12
		(11.71)	(11.76)	(14.00)	(16.22)
	$(p - p^*)_t$	99.66	99.74	99.87	99.94
		(9.86)	(5.62)	(2.87)	(1.24)
	$(e - p + p^*)_t$	1.03	3.56	2.04	1.04
		(0.83)	(12.88)	(12.29)	(12.66)

Table 1.4: Forecast Error Variance Decompositions

Table 1.4c: Model (4) Estimates (CPI's)

Percentage Forecast Error Due To Permanent Relative Price Shock

Country	Variable	1 month	6 months	12 months	24 months
Canada	$(p - p^*)_t$	82.12	88.59	91.38	93.39
		(32.96)	(31.19)	(30.04)	(27.91)
	$(e - p + p^*)_t$	0.22	1.13	1.75	2.25
		(29.68)	(29.70)	(29.91)	(30.25)
France	$(p - p^*)_t$	80.07	87.15	92.90	96.46
		(26.17)	(23.10)	(19.54)	(15.04)
	$(e - p + p^*)_t$	7.95	18.84	32.72	43.75
		(22.08)	(24.50)	(26.27)	(27.33)
Germany	$(p - p^*)_t$	53.71	65.06	68.54	76.12
		(30.92)	(29.11)	(28.05)	(24.26)
	$(e - p + p^*)_t$	33.62	38.10	43.24	46.94
		(29.42)	(29.36)	(29.92)	(30.42)
Italy	$(p - p^*)_t$	59.01	75.74	83.27	89.23
		(33.08)	(30.33)	(28.01)	(24.28)
	$(e - p + p^*)_t$	15.14	34.20	36.22	37.14
		(29.23)	(31.73)	(31.98)	(32.15)
Japan	$(p - p^*)_t$	38.83	48.21	56.83	69.67
		(31.43)	(31.11)	(29.81)	(25.60)
	$(e - p + p^*)_t$	43.71	46.24	46.35	46.38
		(30.95)	(30.55)	(30.44)	(30.48)
UK	$(p - p^*)_t$	76.63	85.31	88.91	92.84
		(30.52)	(28.13)	(26.01)	(21.58)
	$(e - p + p^*)_t$	2.58	5.05	6.89	8.38
		(25.11)	(26.16)	(26.86)	(27.56)

Table 1.4: Forecast Error Variance Decompositions

Table 1.4d: Model (4) Estimates (WPI's)

Percentage Forecast Error Due To Permanent Relative Price Shock

Country	Variable	1 month	6 months	12 months	24 months
Canada	$(p - p^*)_t$	2.84	24.89	37.42	55.32
		(16.12)	(22.94)	(23.55)	(20.99)
	$(e - p + p^*)_t$	80.75	79.89	82.21	83.38
		(23.12)	(22.33)	(21.87)	(21.76)
France	$(p - p^*)_t$	96.95	93.46	91.56	92.07
		(28.31)	(28.49)	(28.28)	(26.28)
	$(e - p + p^*)_t$	6.76	2.86	2.67	2.69
		(29.29)	(28.27)	(28.43)	(28.66)
Germany	$(p - p^*)_t$	22.81	46.21	59.79	75.39
		(24.87)	(25.89)	(23.91)	(18.49)
	$(e - p + p^*)_t$	75.19	70.41	74.30	76.05
		(25.05)	(24.65)	(23.87)	(23.67)
Italy	$(p - p^*)_t$	66.87	84.17	89.97	93.59
		(33.61)	(30.15)	(28.01)	(24.63)
	$(e - p + p^*)_t$	30.59	31.63	33.87	35.53
		(33.54)	(33.47)	(33.56)	(33.74)
Japan	$(p - p^*)_t$	99.69	97.24	96.18	96.63
		(26.19)	(25.74)	(25.91)	(22.64)
	$(e - p + p^*)_t$	15.95	7.61	8.59	9.45
		(30.41)	(28.13)	(28.60)	(29.03)
UK	$(p - p^*)_t$	43.39	65.86	79.26	88.21
		(31.29)	(29.31)	(25.28)	(20.53)
	$(e - p + p^*)_t$	40.77	32.80	37.89	42.12
		(30.77)	(29.01)	(29.21)	(29.64)

Each element reports the percentage of the **Variable's** total forecast error variance attributable to the permanent relative price disturbance in Model (1). Standard errors computed by Monte Carlo integration are in parentheses and are based on 2500 random draws.

Figure 1.1a: Canada/US Nominal Exchange Rate And Relative Prices

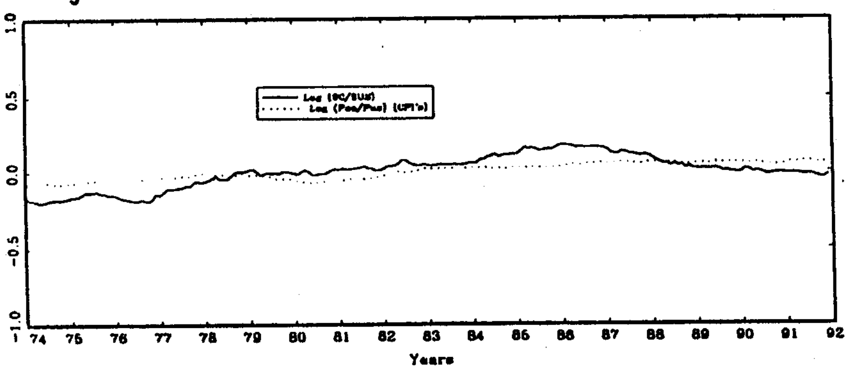


Figure 1.1b: France/US Nominal Exchange Rate And Relative Prices

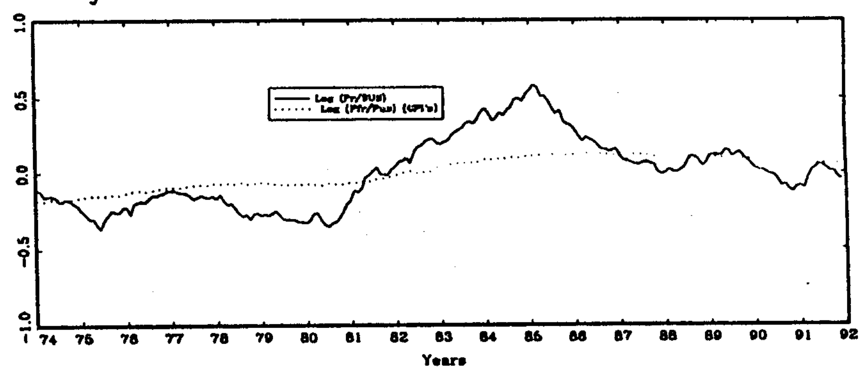


Figure 1.1c: Germany/US Nominal Exchange Rate And Relative Prices

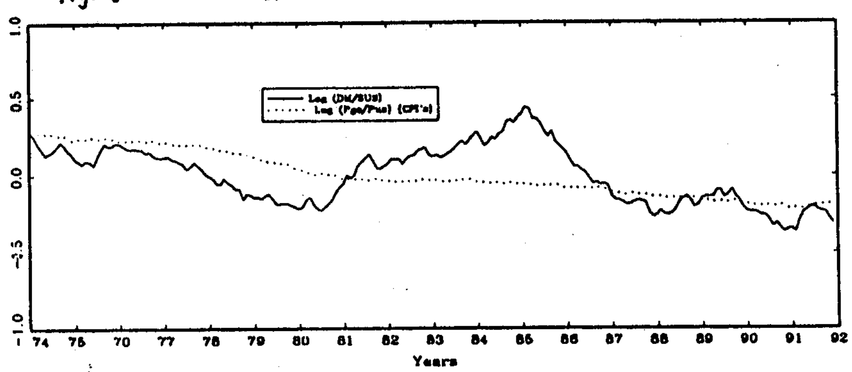


Figure 1.1d: Italy/US Nominal Exchange Rate And Relative Prices

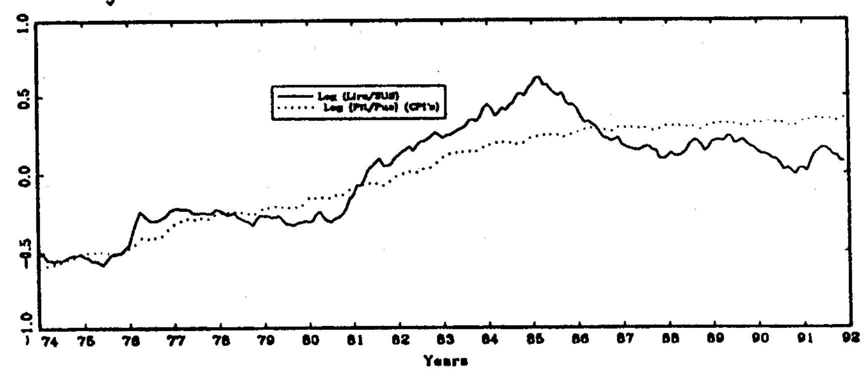


Figure 1.1e: Japan/US Nominal Exchange Rate And Relative Prices

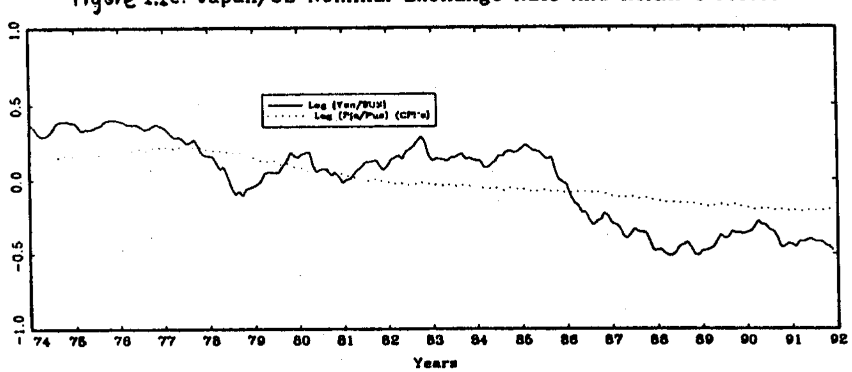


Figure 1.1f: UK/US Nominal Exchange Rate And Relative Prices

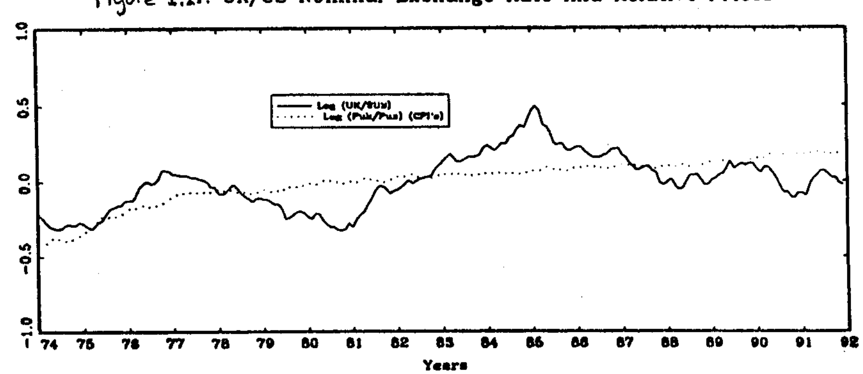


Figure 1.2a: Canada/US Nominal Exchange Rate And Relative Prices

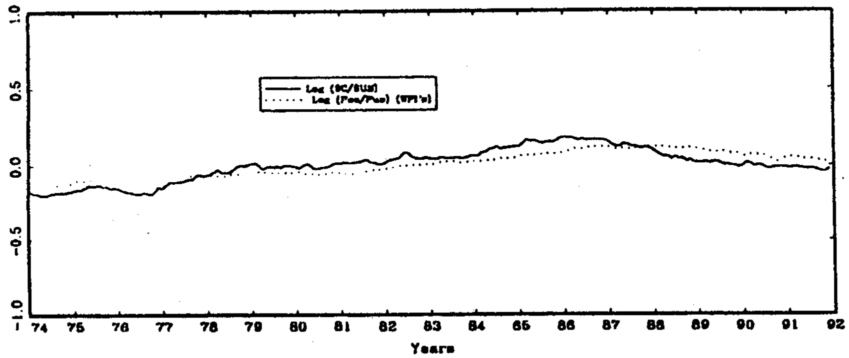


Figure 1.2b: France/US Nominal Exchange Rate And Relative Prices

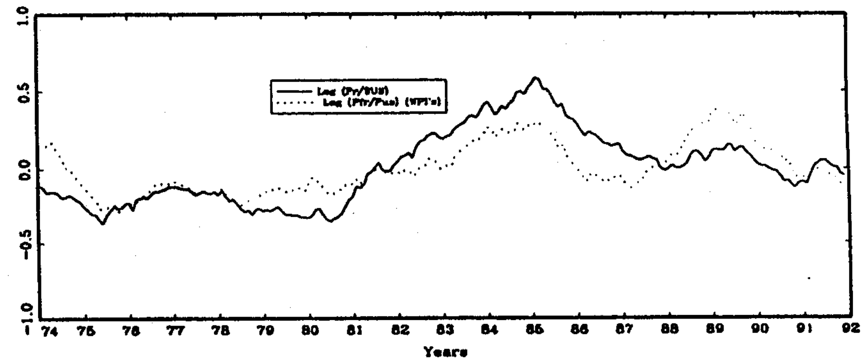


Figure 1.2c: Germany/US Nominal Exchange Rate And Relative Prices

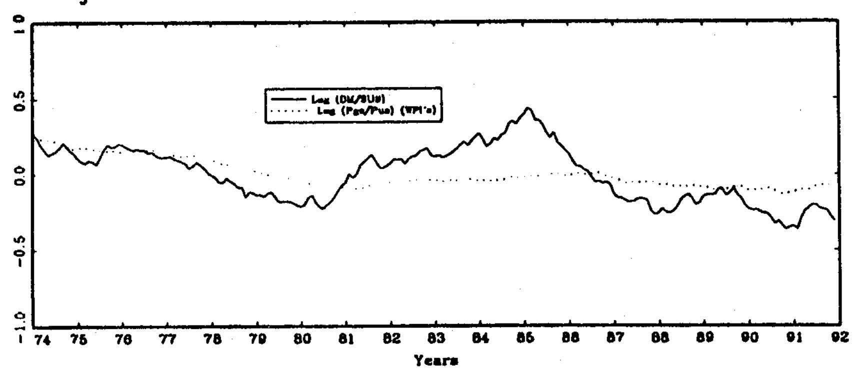


Figure 1.2d: Italy/US Nominal Exchange Rate And Relative Prices

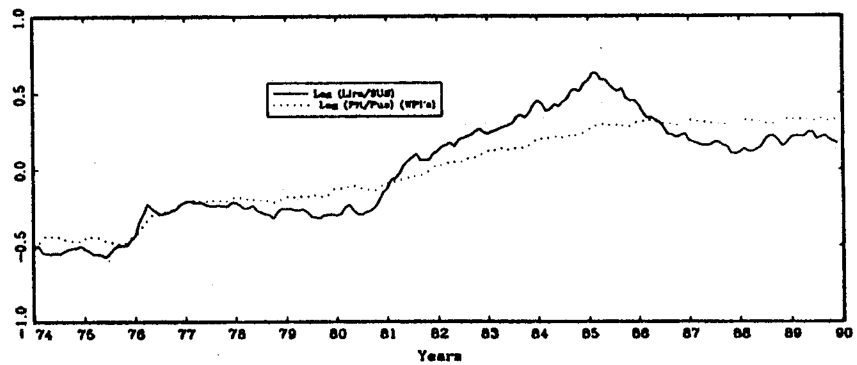


Figure 1.2e: Japan/US Nominal Exchange Rate And Relative Prices

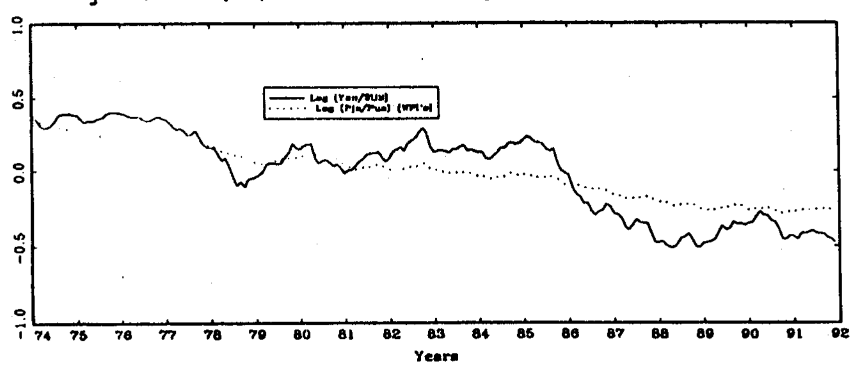


Figure 1.2f: UK/US Nominal Exchange Rate And Relative Prices

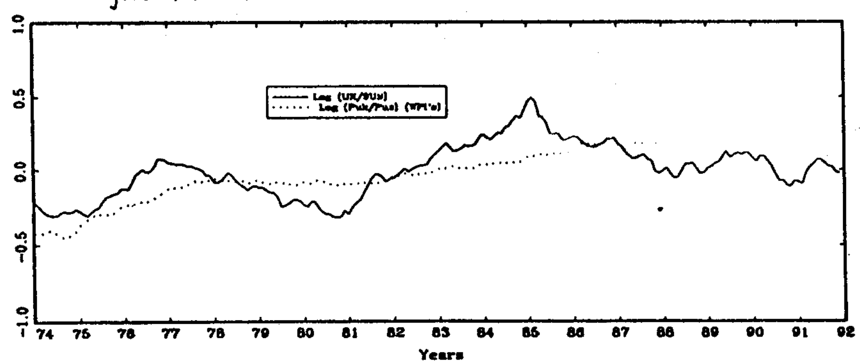


Figure 1.3a: Canada/US Real Exchange Rate

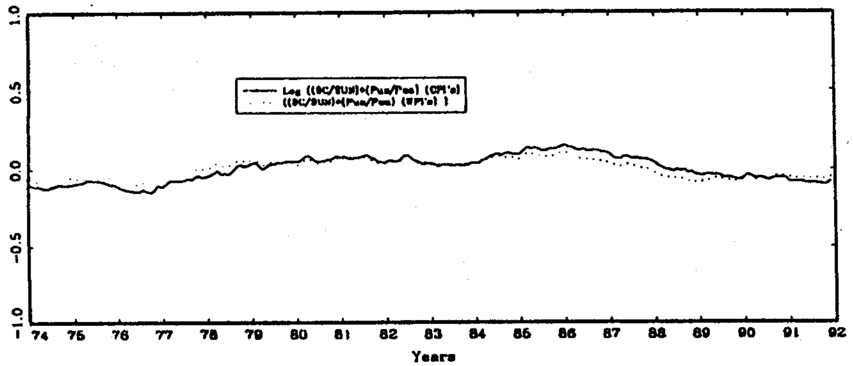


Figure 1.3b: France/US Real Exchange Rate

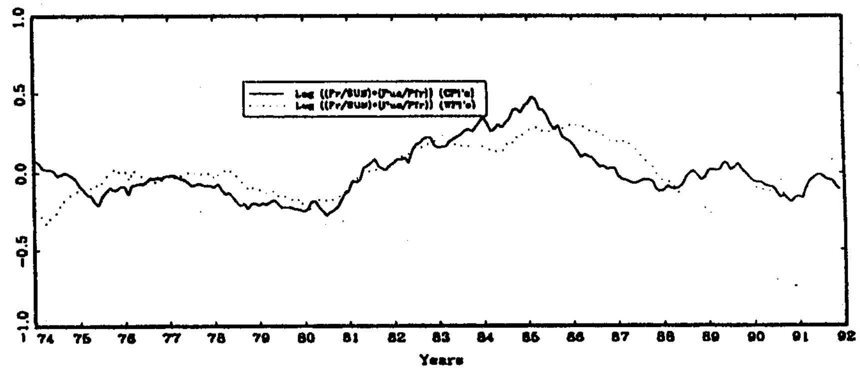


Figure 1.3c: Germany/US Real Exchange Rate

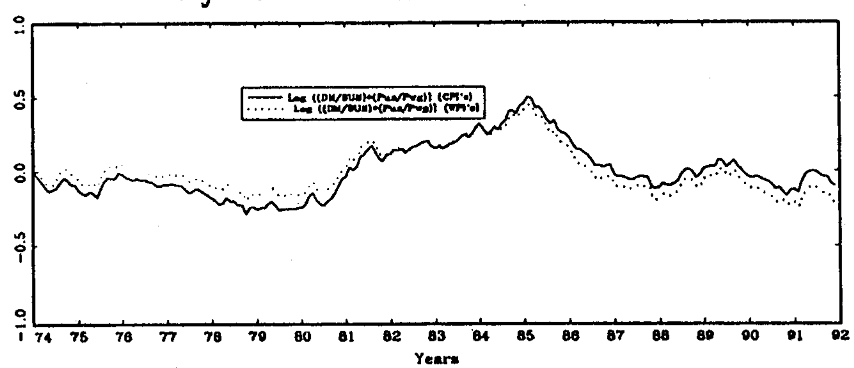


Figure 1.3d: Italy/US Real Exchange Rate

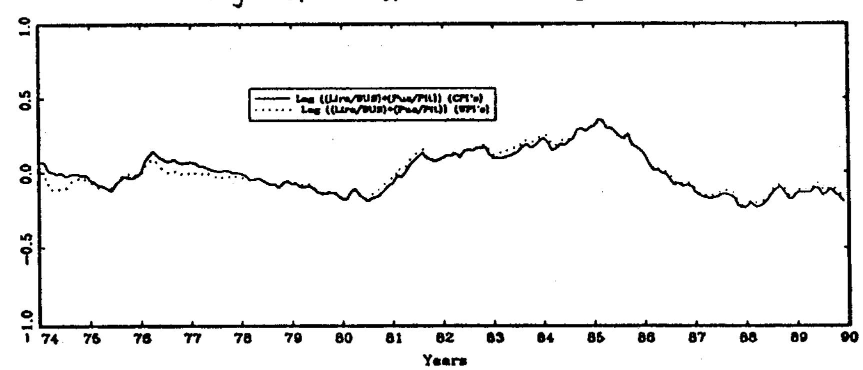


Figure 1.3e: Japan/US Real Exchange Rate

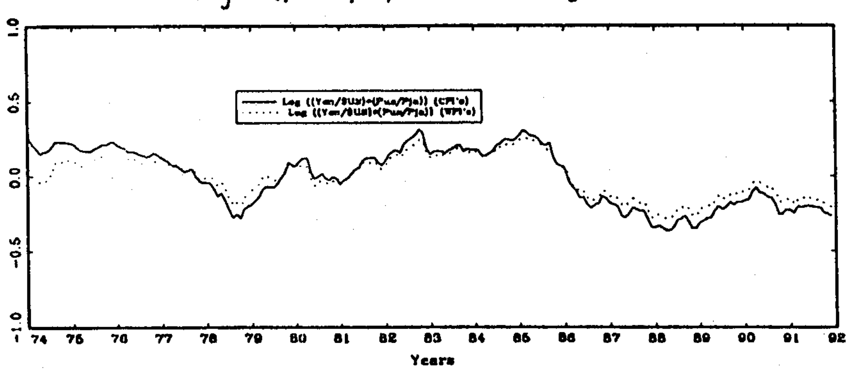


Figure 1.3f: UK/US Real Exchange Rate

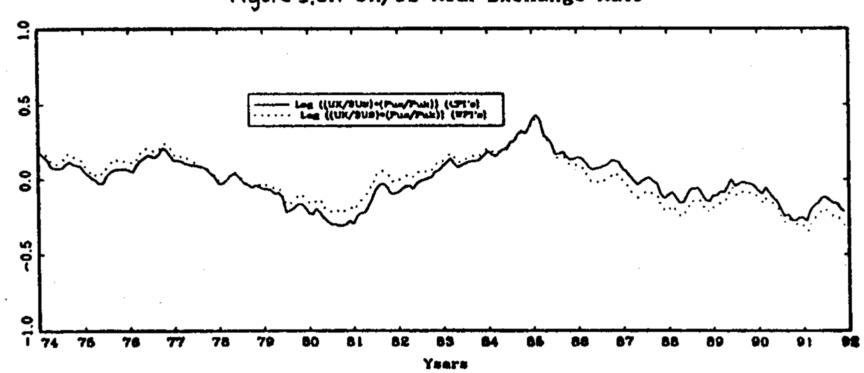


Figure 1.4a: Canada/US $p-p^*$ response to permanent $p-p^*$ shock

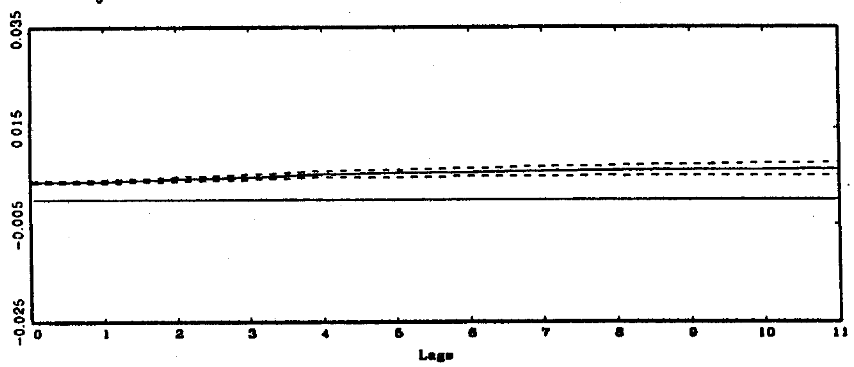


Figure 1.4b: Canada/US $p-p^*$ response to transitory $p-p^*$ shock

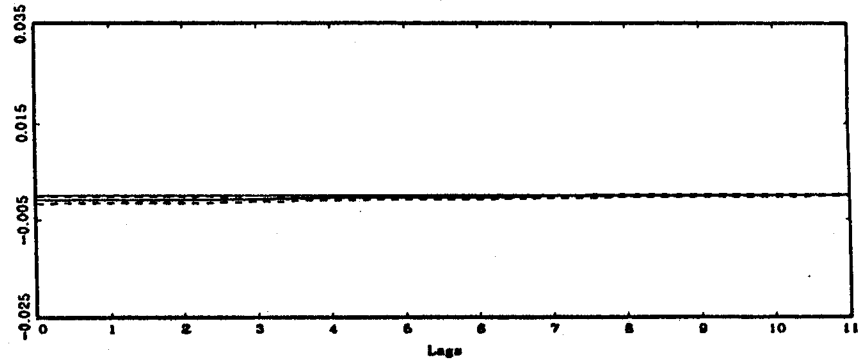


Figure 1.4c: Canada/US e response to permanent $p-p^*$ shock

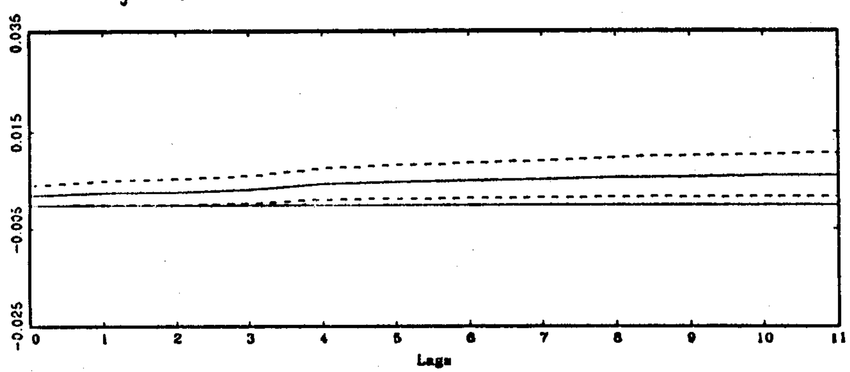


Figure 1.4d: Canada/US e response to transitory $p-p^*$ shock

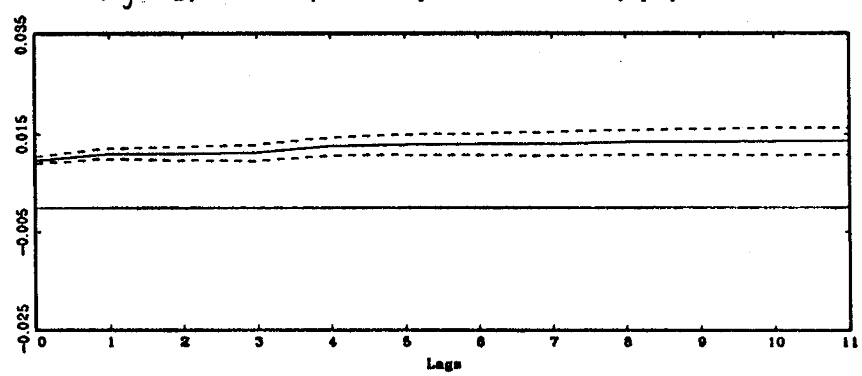


Figure 1.4e: Canada/US $e-p+p^*$ response to permanent $p-p^*$ shock

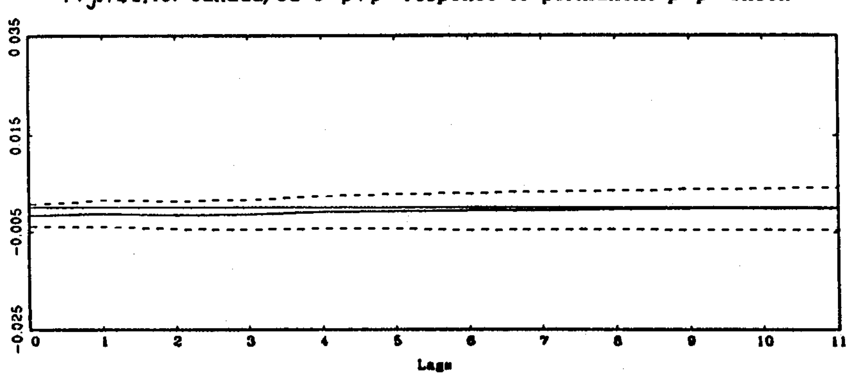


Figure 1.4f: Canada/US $e-p+p^*$ response to transitory $p-p^*$ shock

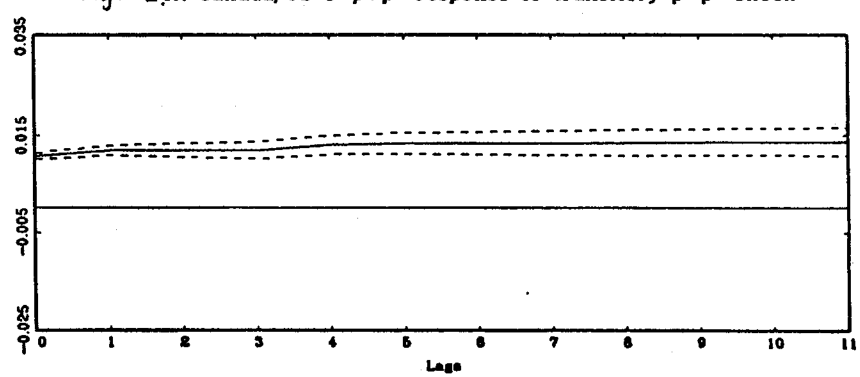


Figure 1.4(wp)a: Canada/US p−p* response to permanent p−p* shock

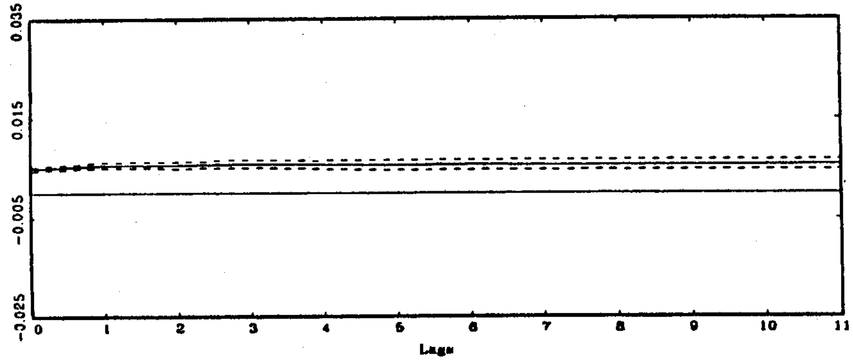


Figure 1.4(wp)b: Canada/US p−p* response to transitory p−p* shock

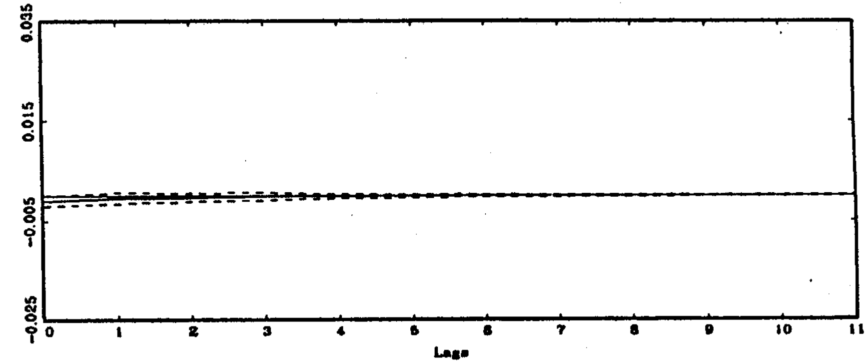


Figure 1.4(wp)c: Canada/US e response to permanent p−p* shock

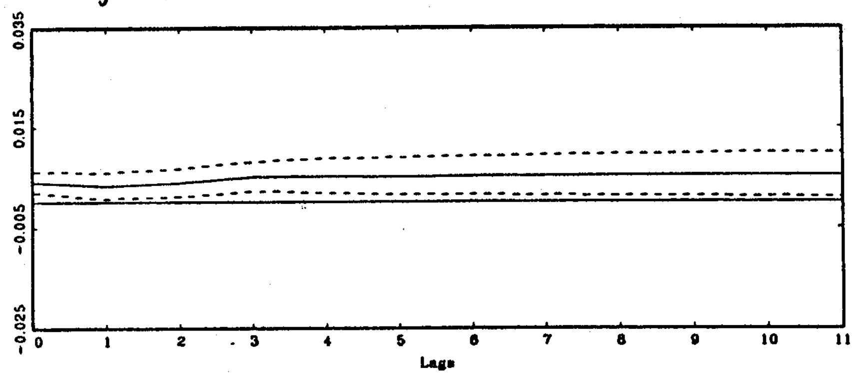


Figure 1.4(wp)d: Canada/US e response to transitory p−p* shock

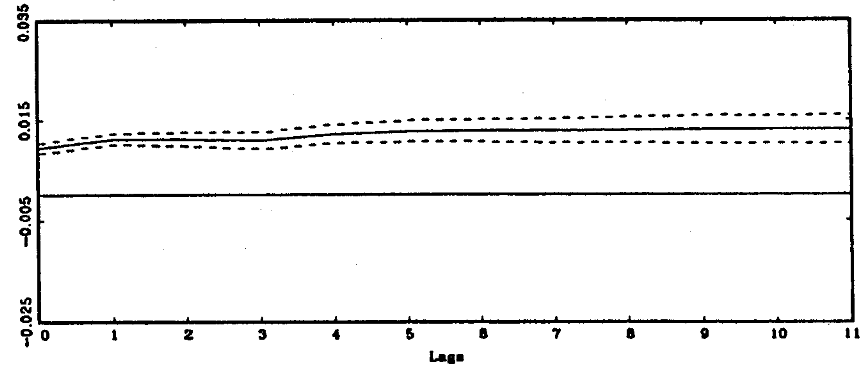


Figure 1.4(wp)e: Canada/US e−p+p* response to permanent p−p* shock

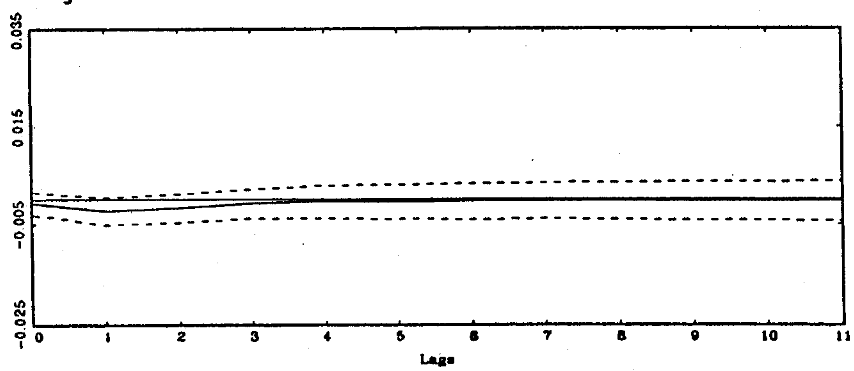
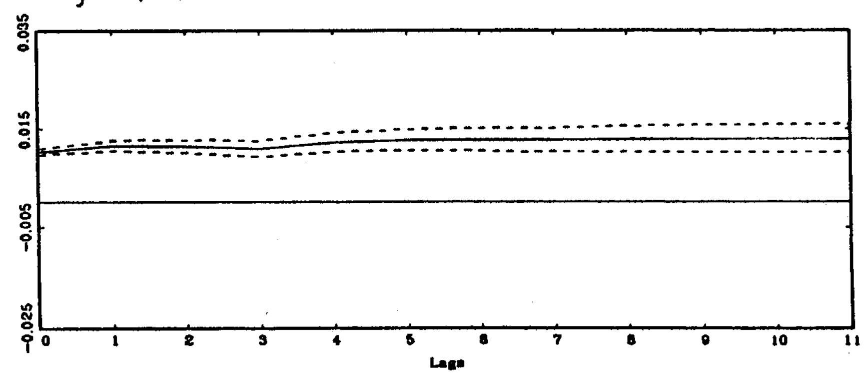


Figure 1.4(wp)f: Canada/US e−p+p* response to transitory p−p* shock



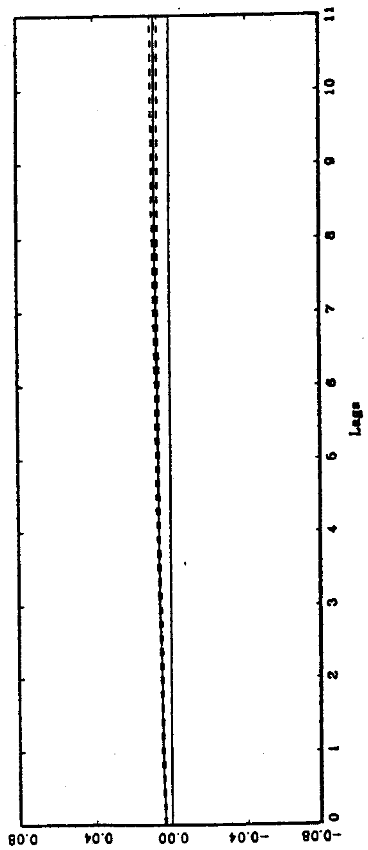


Figure 1.5a: France/US p-p* response to permanent p-p* shock

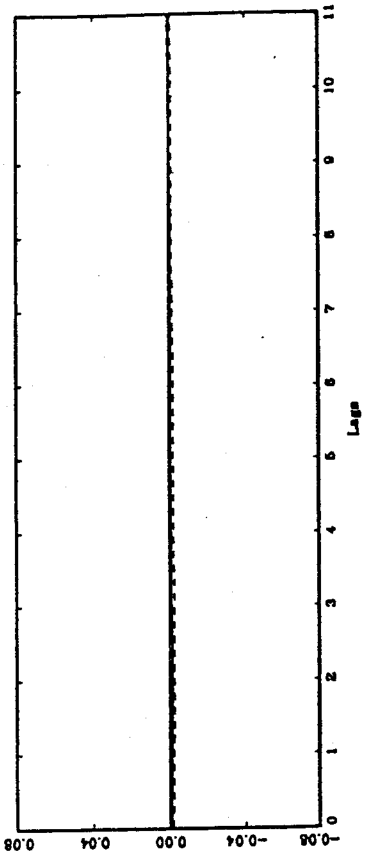


Figure 1.5b: France/US p-p* response to transitory p-p* shock

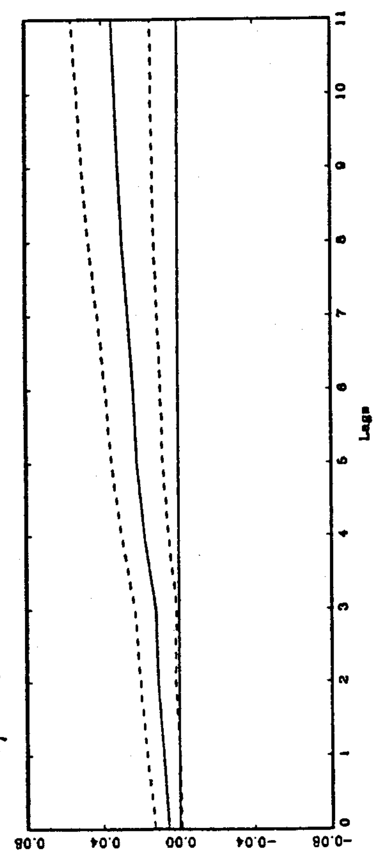


Figure 1.5c: France/US e response to permanent p-p* shock

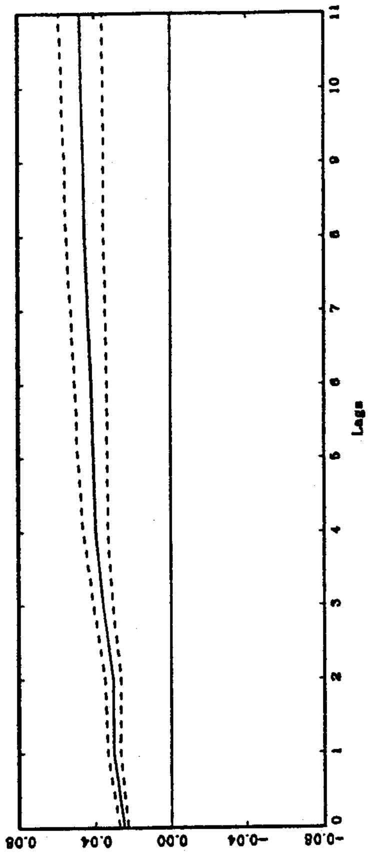


Figure 1.5d: France/US e response to transitory p-p* shock

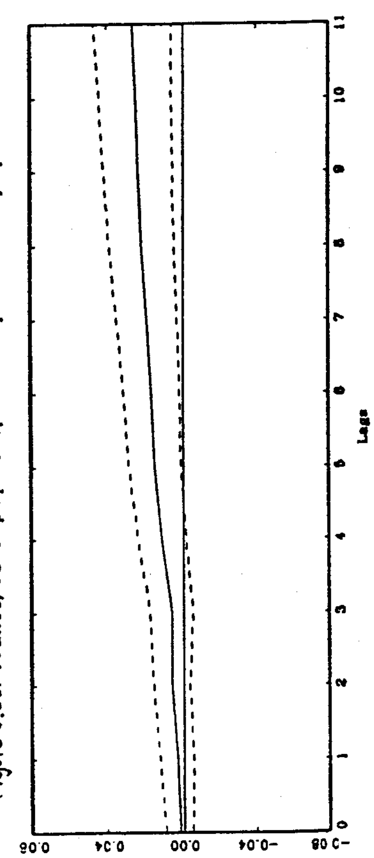


Figure 1.5e: France/US e-p+p* response to permanent p-p* shock

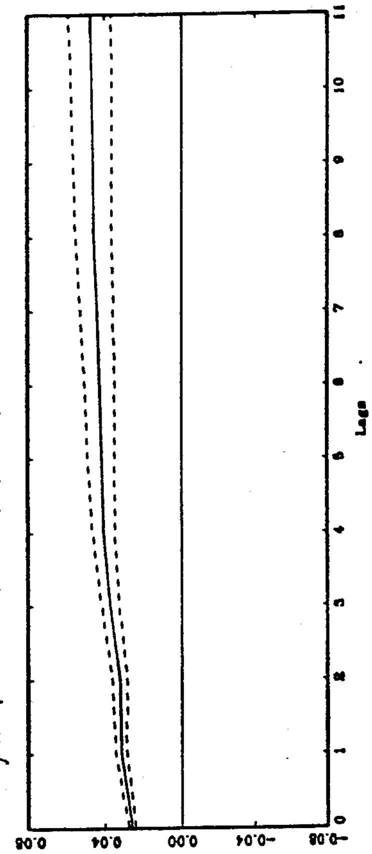


Figure 1.5f: France/US e-p+p* response to transitory p-p* shock

Figure 1.5(wp)a: France/US p−p* response to permanent p−p* shock

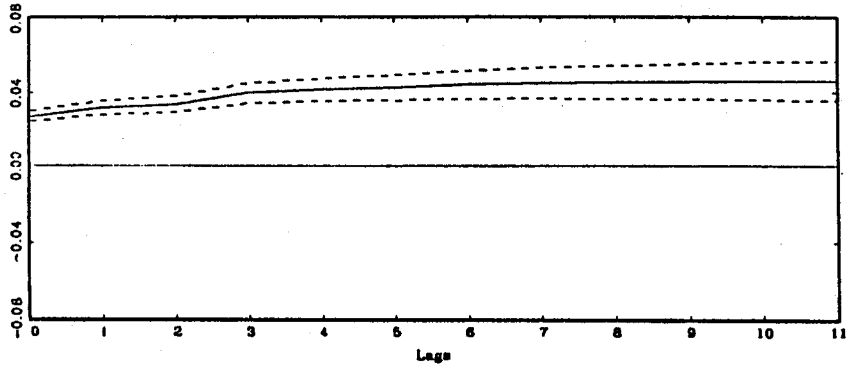


Figure 1.5(wp)b: France/US p−p* response to transitory p−p* shock

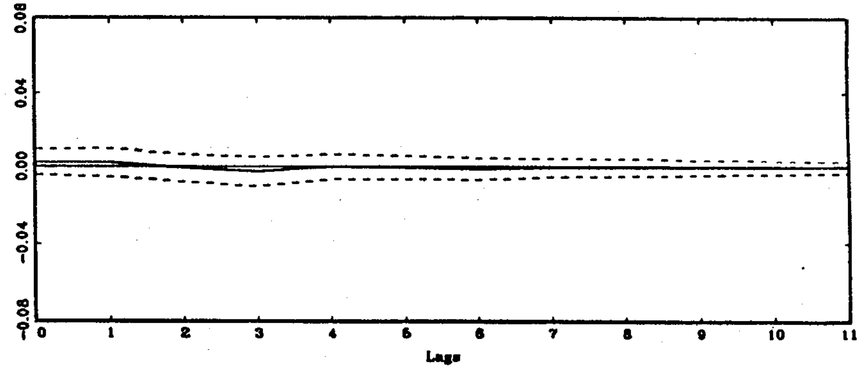


Figure 1.5(wp)c: France/US e response to permanent p−p* shock

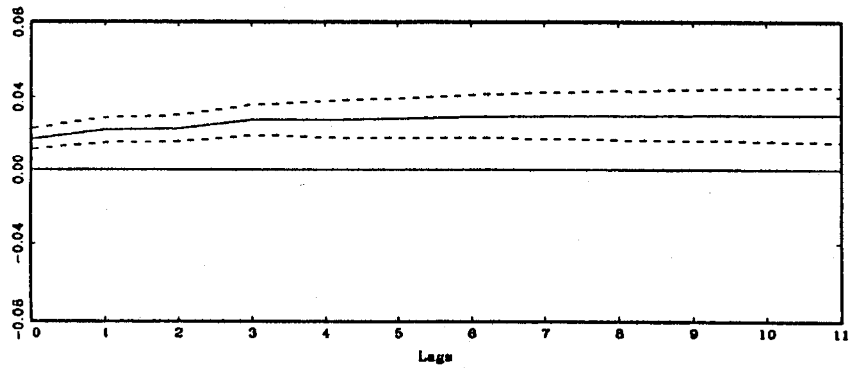


Figure 1.5(wp)d: France/US e response to transitory p−p* shock

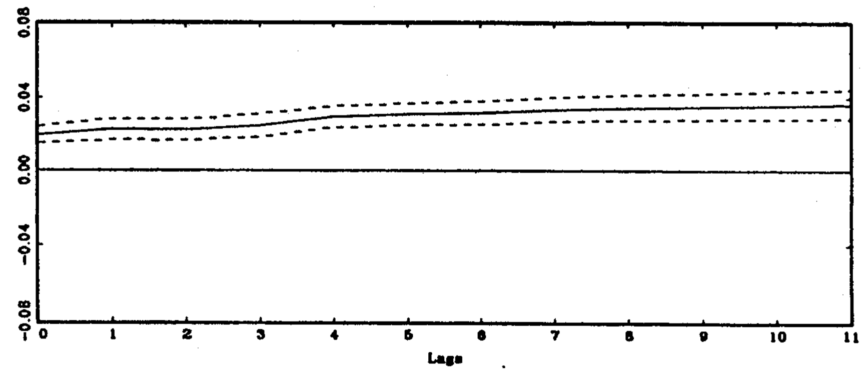


Figure 1.5(wp)e: France/US e−p+p* response to permanent p−p* shock

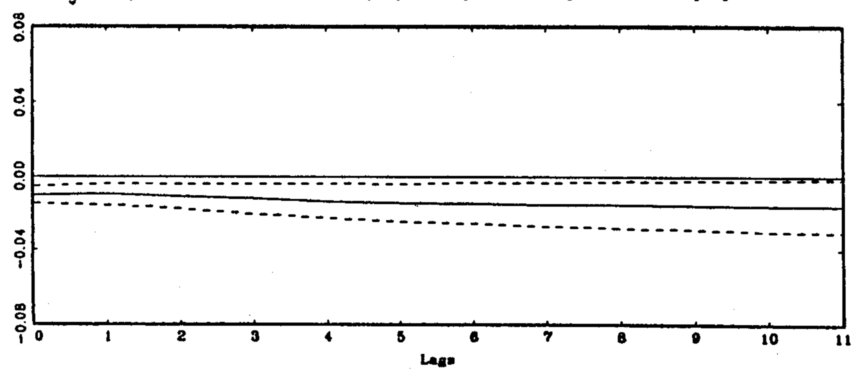
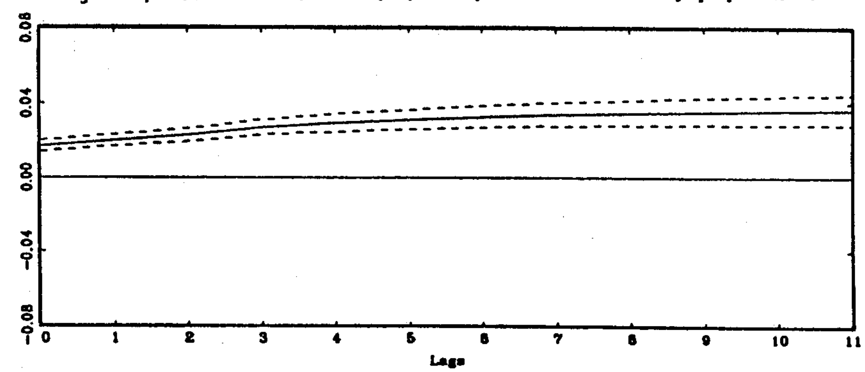


Figure 1.5(wp)f: France/US e−p+p* response to transitory p−p* shock



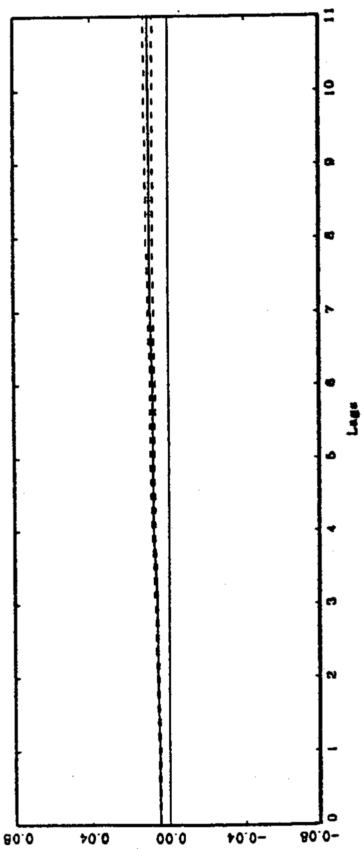


Figure 1.6a: Germany/US p−p* response to permanent p−p* shock

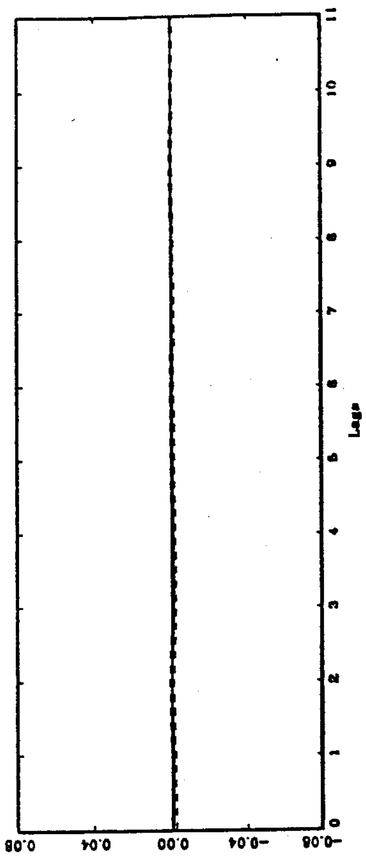


Figure 1.6b: Germany/US p−p* response to transitory p−p* shock

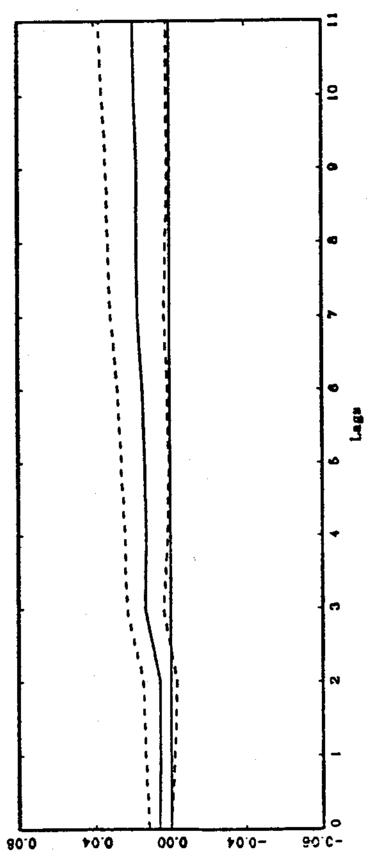


Figure 1.6c: Germany/US e response to permanent p−p* shock

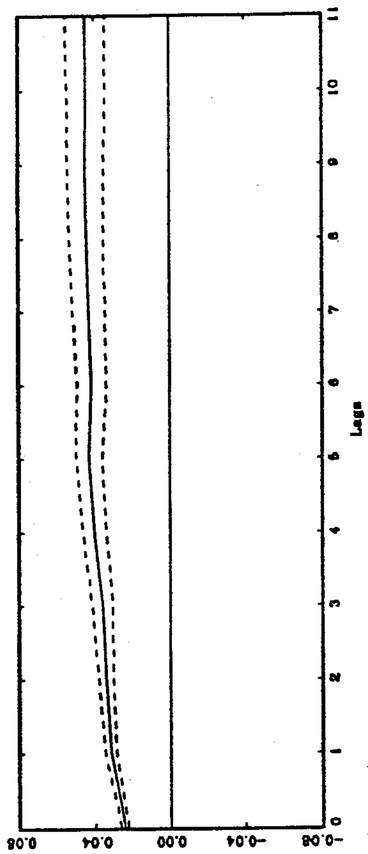


Figure 1.6d: Germany/US e response to transitory p−p* shock

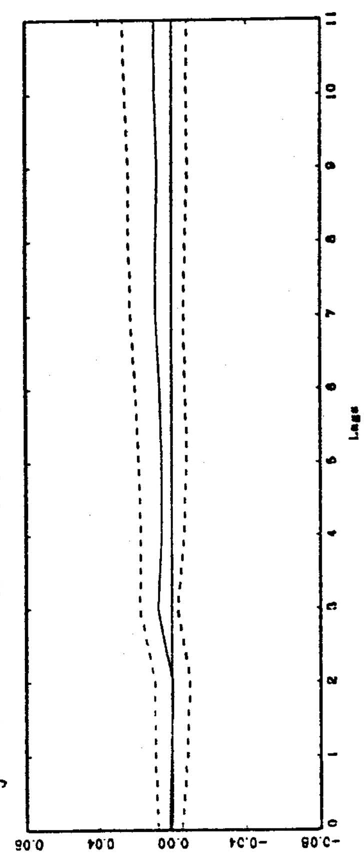


Figure 1.6e: Germany/US e−p+p* response to permanent p−p* shock

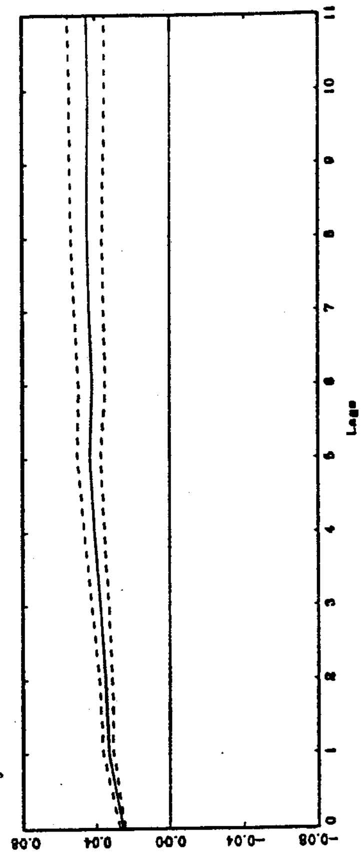


Figure 1.6f: Germany/US e−p+p* response to transitory p−p* shock

Figure 1.6(wp)a: Germany/US p−p* response to permanent p−p* shock

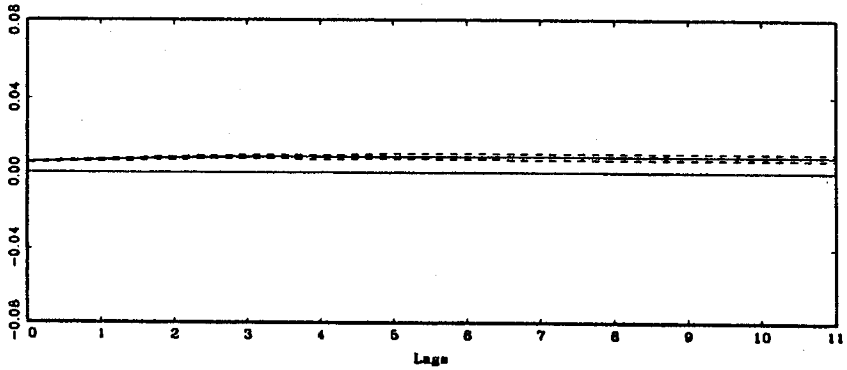


Figure 1.6(wp)b: Germany/US p−p* response to transitory p−p* shock

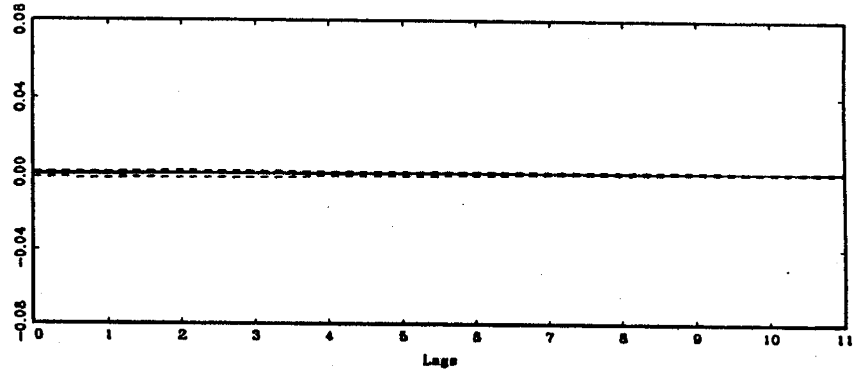


Figure 1.6(wp)c: Germany/US e response to permanent p−p* shock

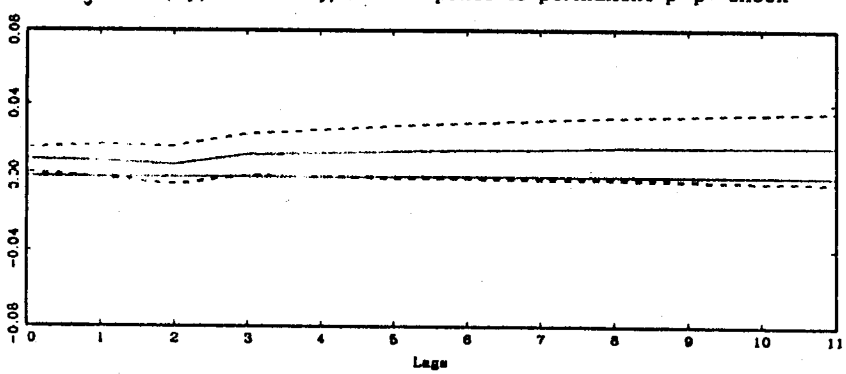


Figure 1.6(wp)d: Germany/US e response to transitory p−p* shock

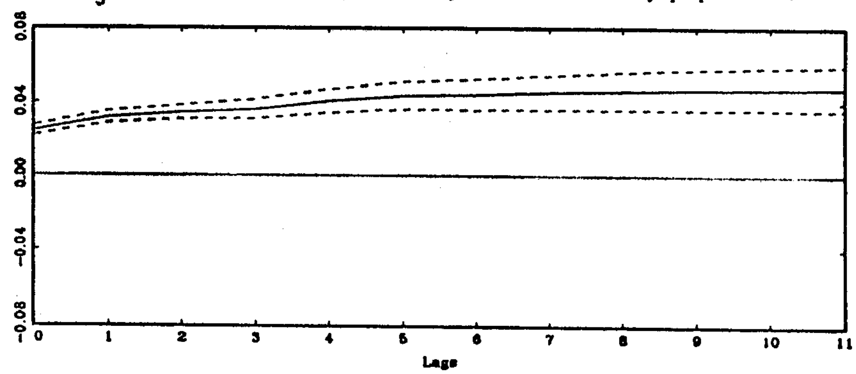


Figure 1.6(wp)e: Germany/US e−p+p* response to permanent p−p* shock

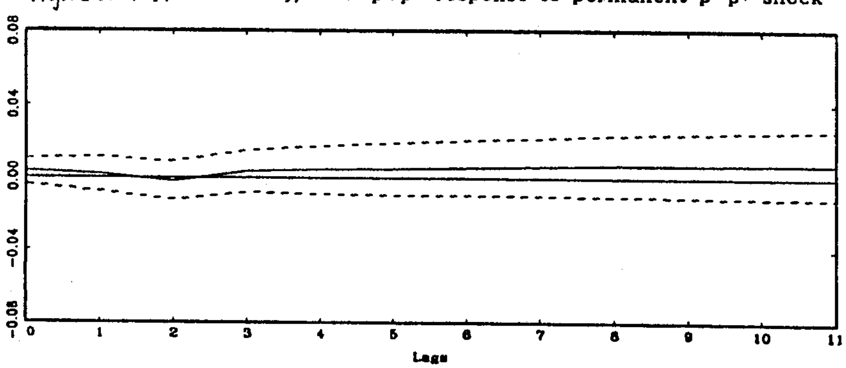


Figure 1.6(wp)f: Germany/US e−p+p* response to transitory p−p* shock

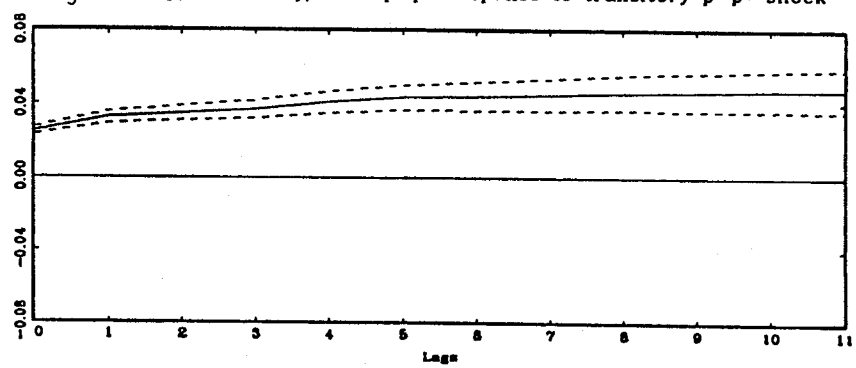


Figure 1.7a: Italy/US p−p* response to permanent p−p* shock

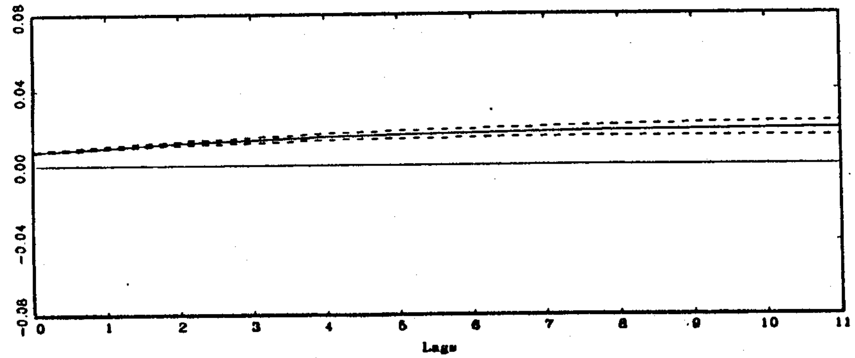


Figure 1.7b: Italy/US p−p* response to transitory p−p* shock

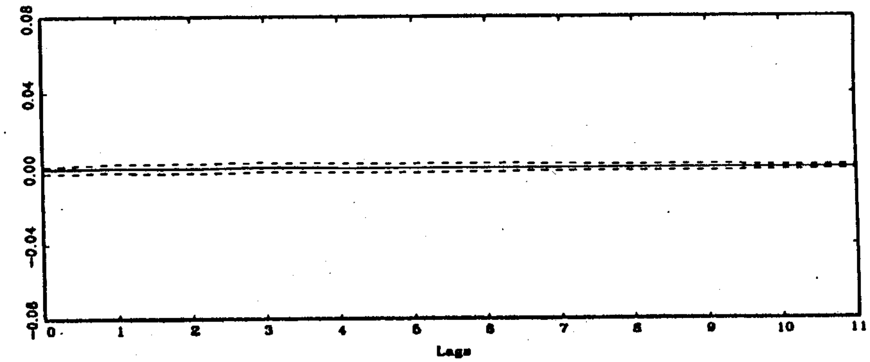


Figure 1.7c: Italy/US e response to permanent p−p* shock

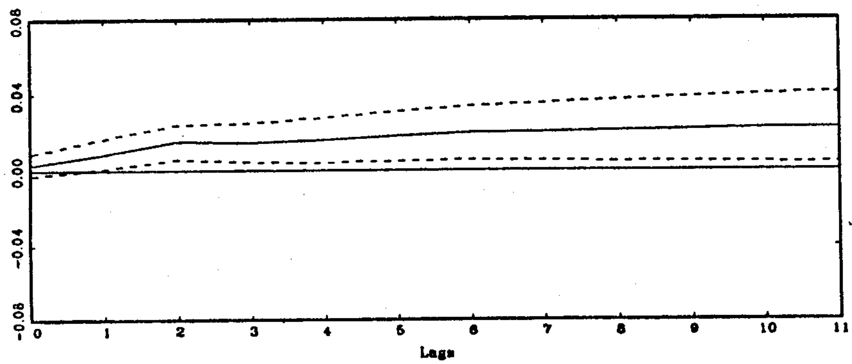


Figure 1.7d: Italy/US e response to transitory p−p* shock

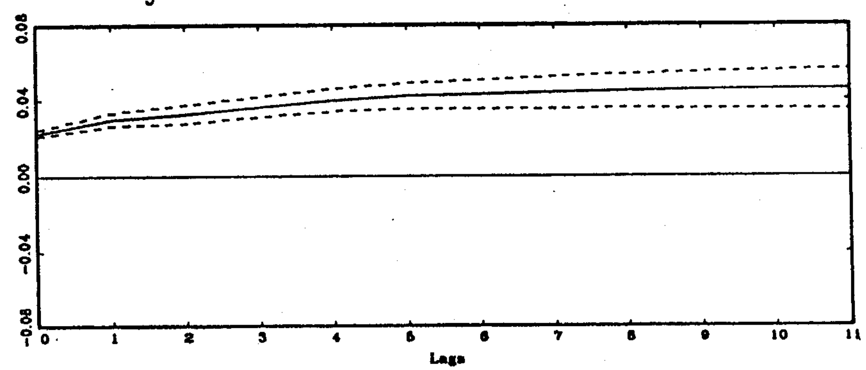


Figure 1.7e: Italy/US e−p+p* response to permanent p−p* shock

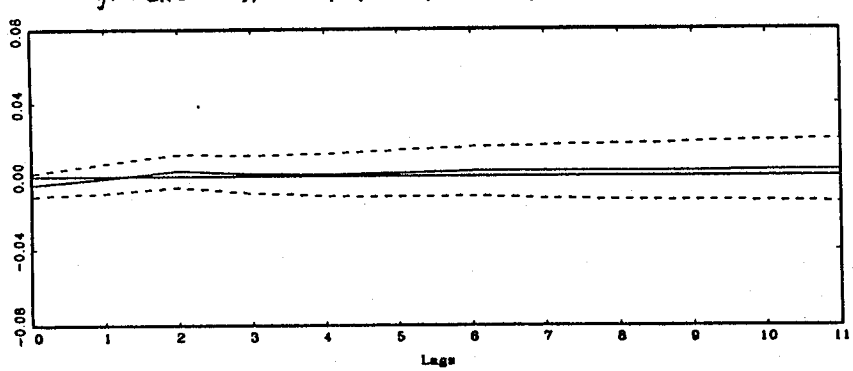
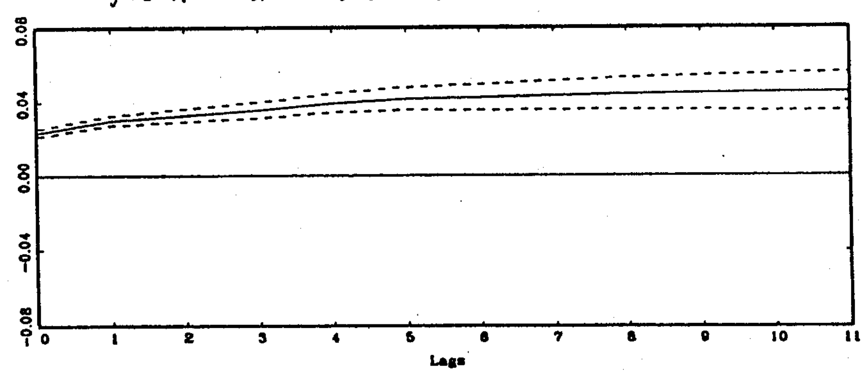


Figure 1.7f: Italy/US e−p+p* response to transitory p−p* shock



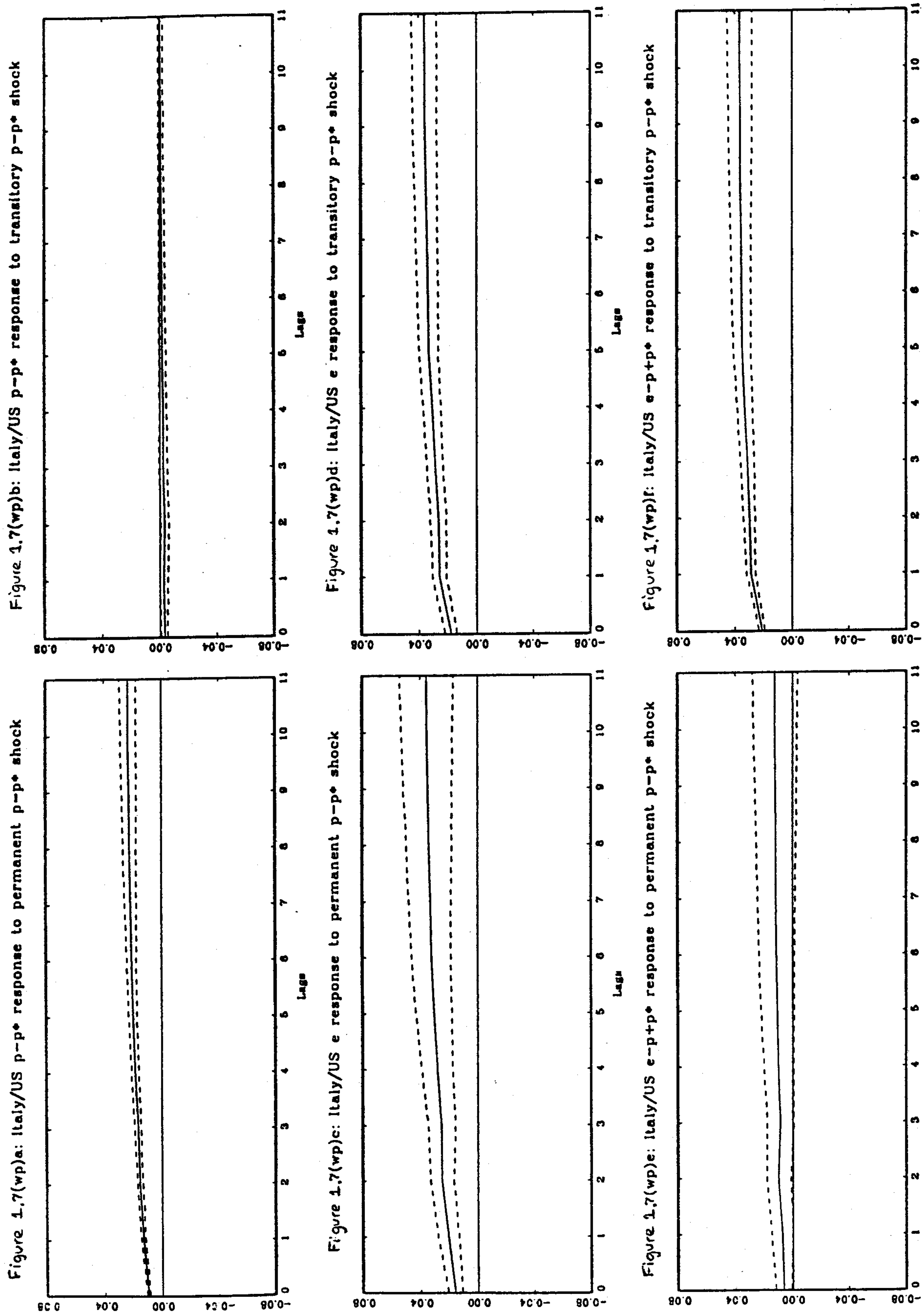


Figure 1.7(wp)a: Italy/US p-p* response to permanent p-p* shock
Figure 1.7(wp)b: Italy/US p-p* response to transitory p-p* shock
Figure 1.7(wp)c: Italy/US e response to permanent p-p* shock
Figure 1.7(wp)d: Italy/US e response to transitory p-p* shock
Figure 1.7(wp)e: Italy/US e-p+p* response to permanent p-p* shock
Figure 1.7(wp)f: Italy/US e-p+p* response to transitory p-p* shock
Lags
0.08
0.04
0.00
-0.04
-0.08

Figure 1.8a: Japan/US p−p* response to permanent p−p* shock

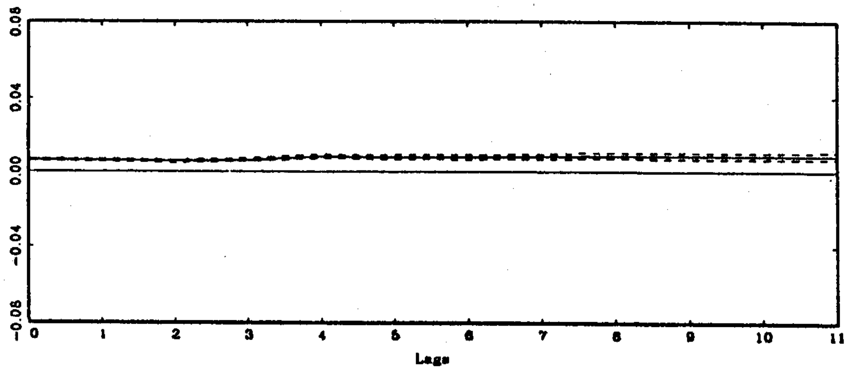


Figure 1.8b: Japan/US p−p* response to transitory p−p* shock

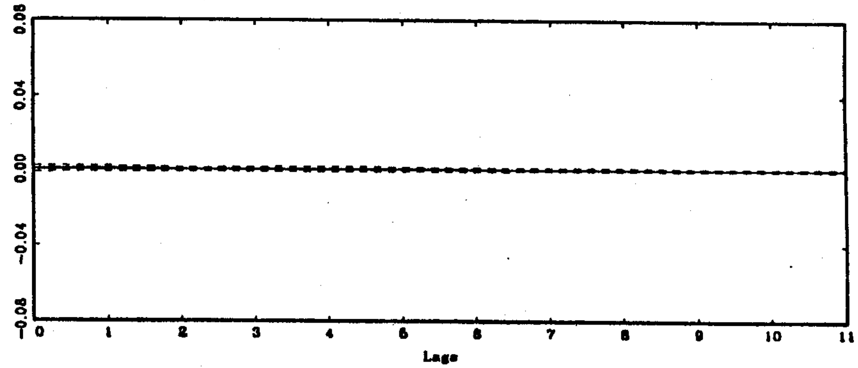


Figure 1.8c: Japan/US e response to permanent p−p* shock

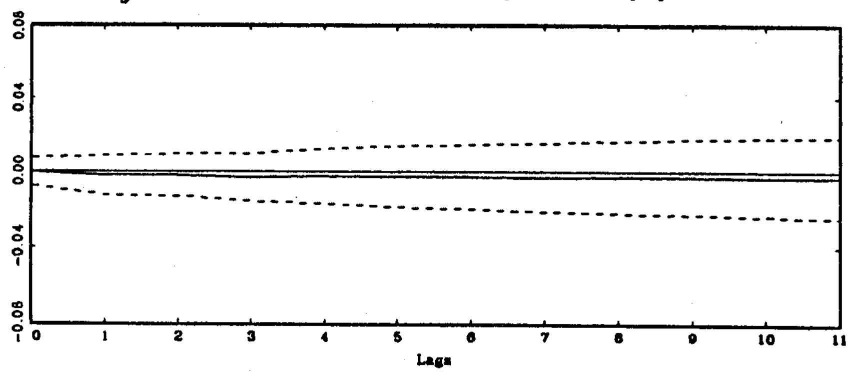


Figure 1.8d: Japan/US e response to transitory p−p* shock

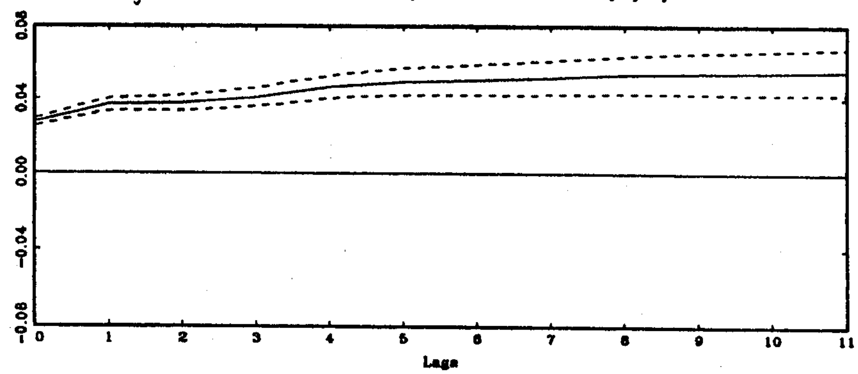


Figure 1.8e: Japan/US e−p+p* response to permanent p−p* shock

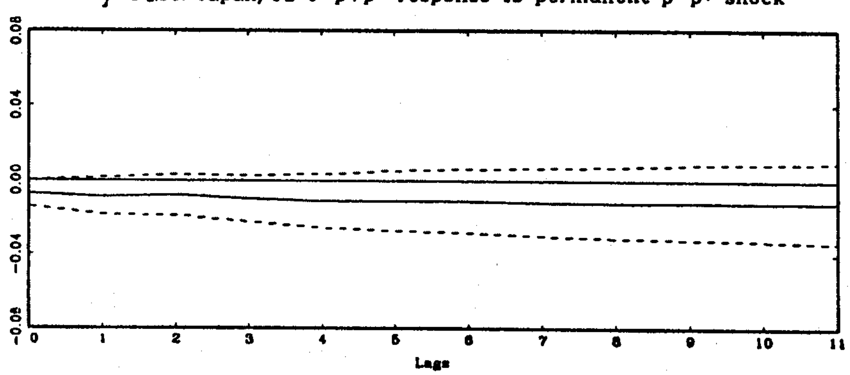


Figure 1.8f: Japan/US e−p+p* response to transitory p−p* shock

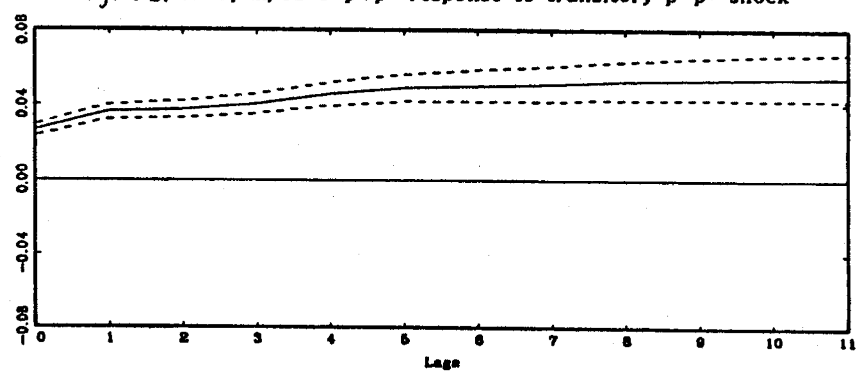


Figure 1.8(wp)a: Japan/US p-p* response to permanent p-p* shock

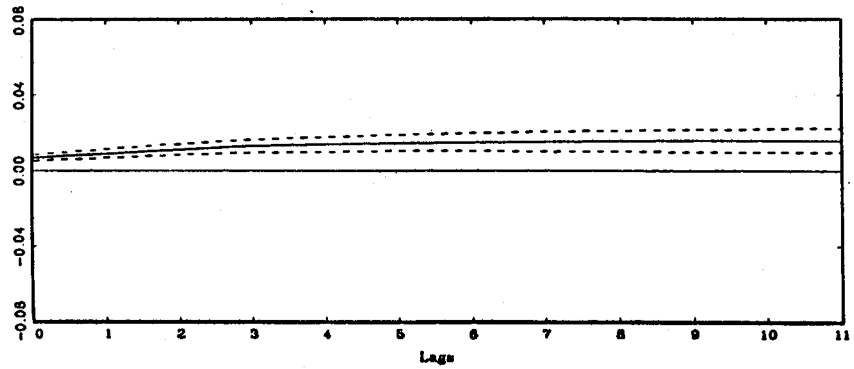


Figure 1.8(wp)b: Japan/US p-p* response to transitory p-p* shock

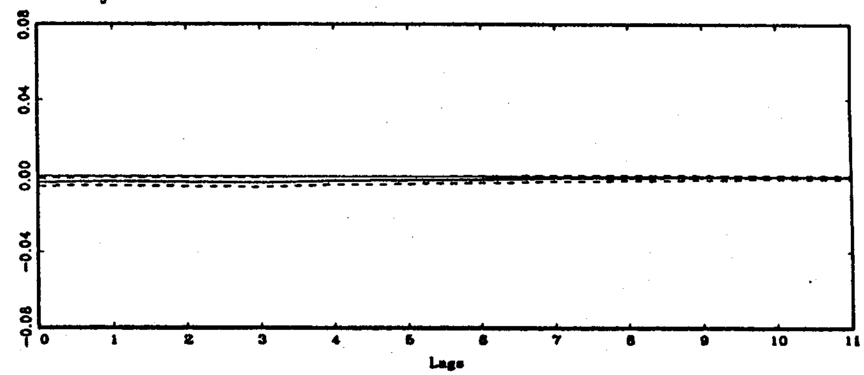


Figure 1.8(wp)c: Japan/US e response to permanent p-p* shock

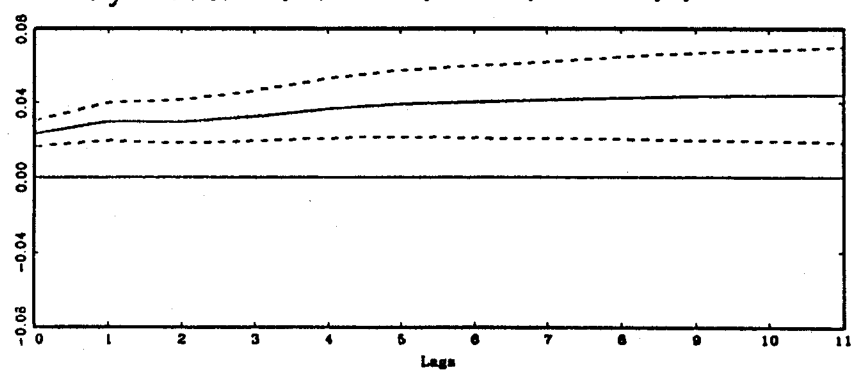


Figure 1.8(wp)d: Japan/US e response to transitory p-p* shock

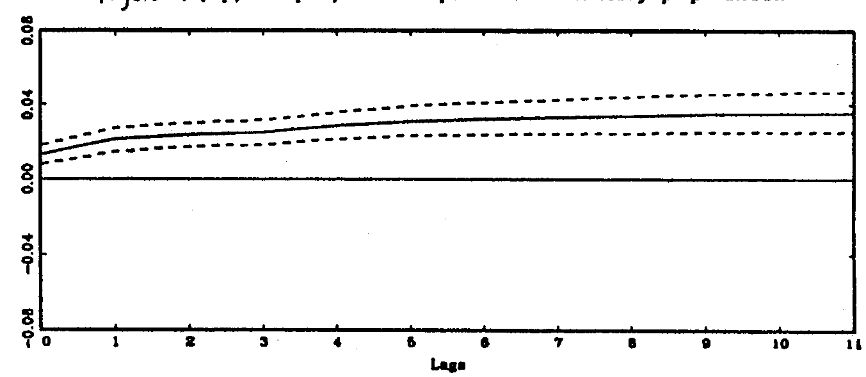


Figure 1.8(wp)e: Japan/US e-p+p* response to permanent p-p* shock

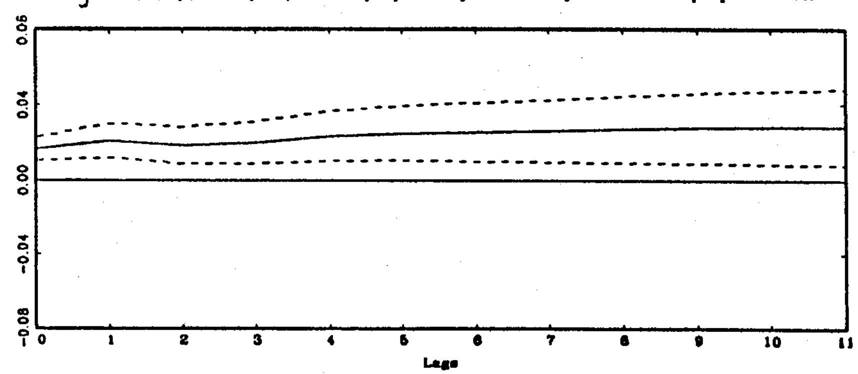


Figure 1.8(wp)f: Japan/US e-p+p* response to transitory p-p* shock

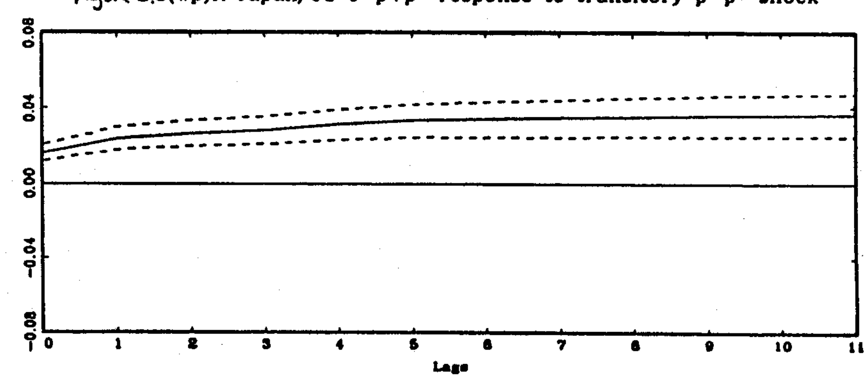


Figure 1.9a: UK/US p-p* response to permanent p-p* shock

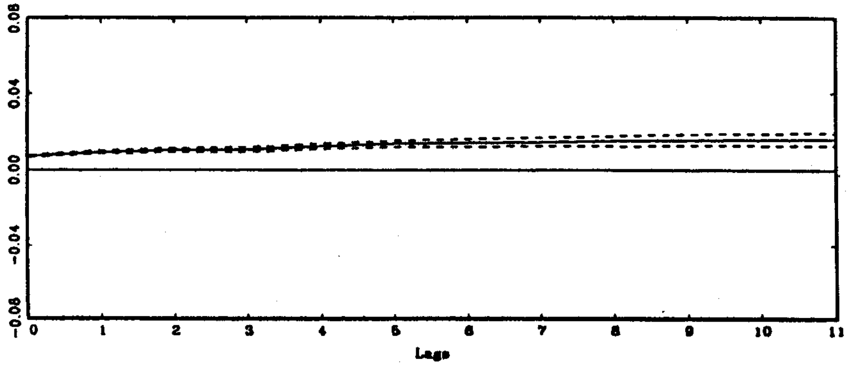


Figure 1.9b: UK/US p-p* response to transitory p-p* shock

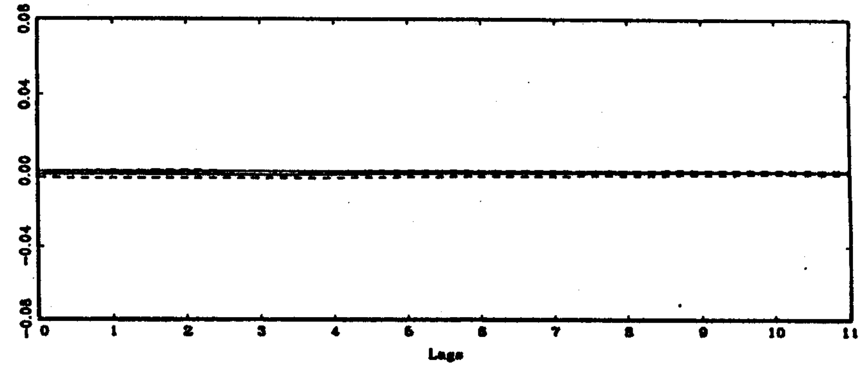


Figure 1.9c: UK/US e response to permanent p-p* shock

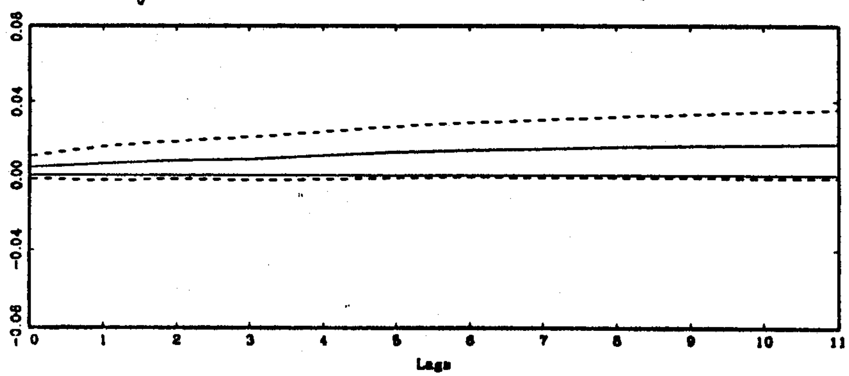


Figure 1.9d: UK/US e response to transitory p-p* shock

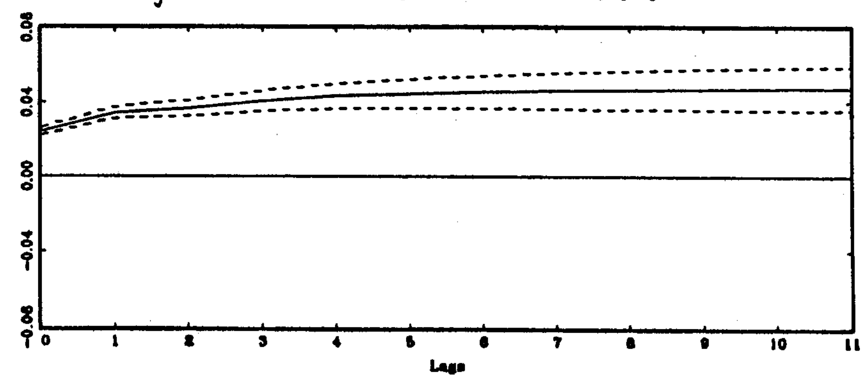


Figure 1.9e: UK/US e-p+p* response to permanent p-p* shock

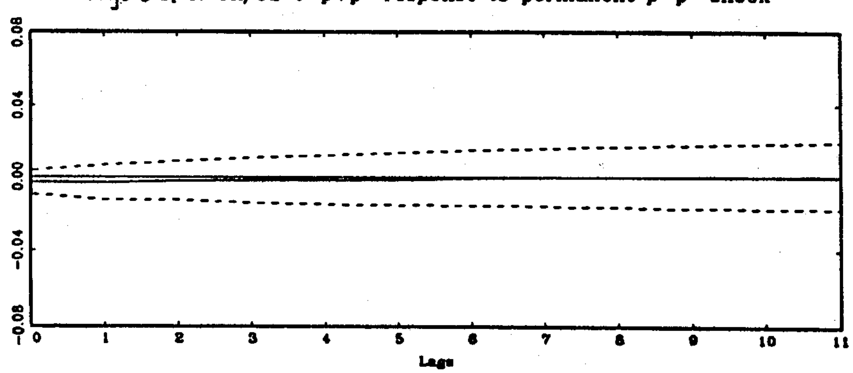


Figure 1.9f: UK/US e-p+p* response to transitory p-p* shock

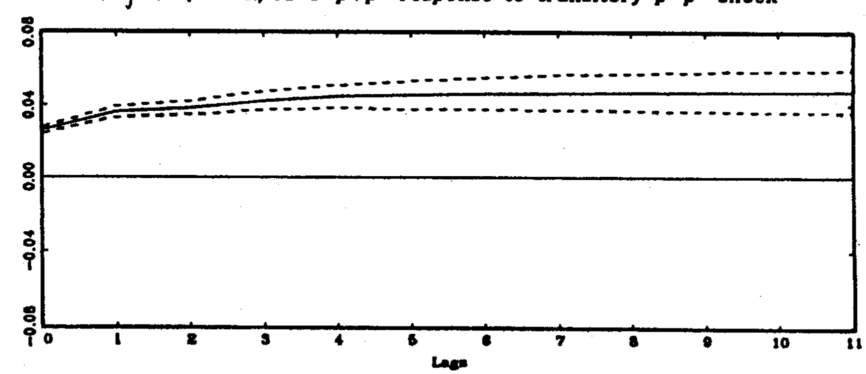


Figure 1.9(wp)a: UK/US p−p* response to permanent p−p* shock

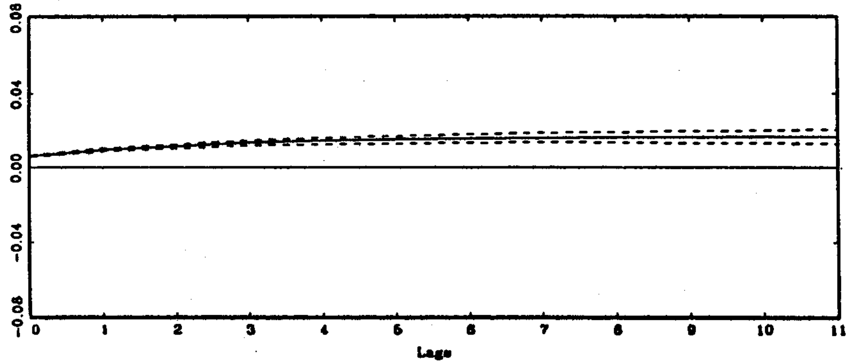


Figure 1.9(wp)b: UK/US p−p* response to transitory p−p* shock

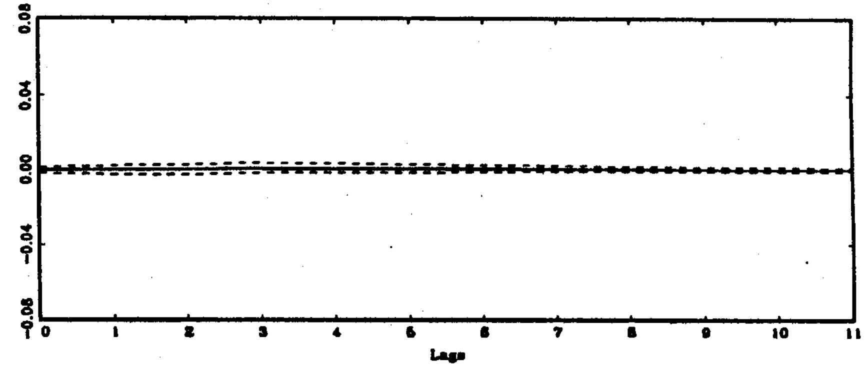


Figure 1.9(wp)c: UK/US e response to permanent p−p* shock

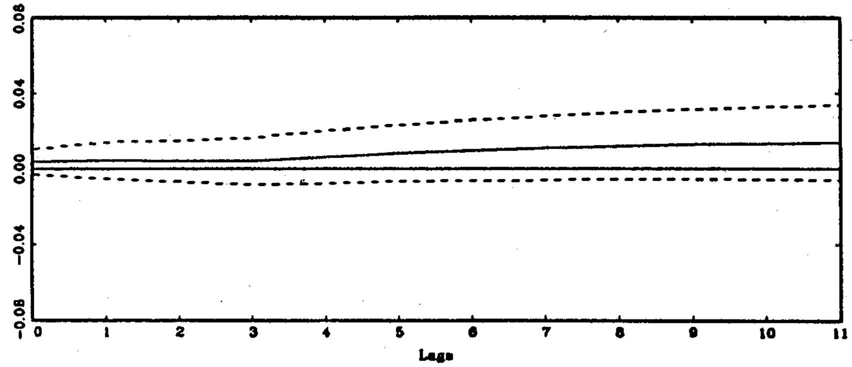


Figure 1.9(wp)d: UK/US e response to transitory p−p* shock

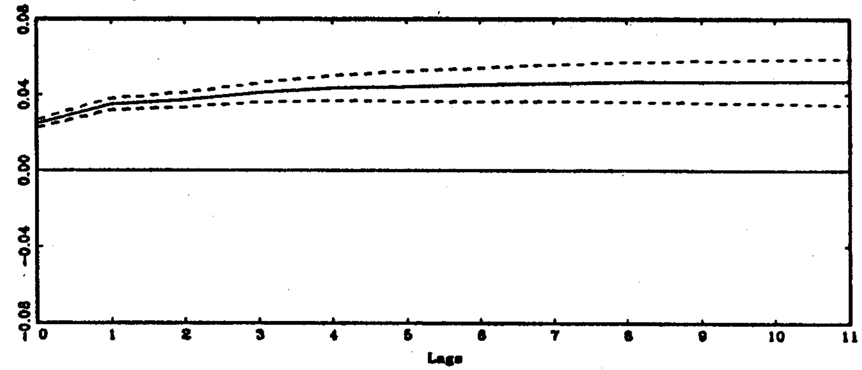


Figure 1.9(wp)e: UK/US e−p+p* response to permanent p−p* shock

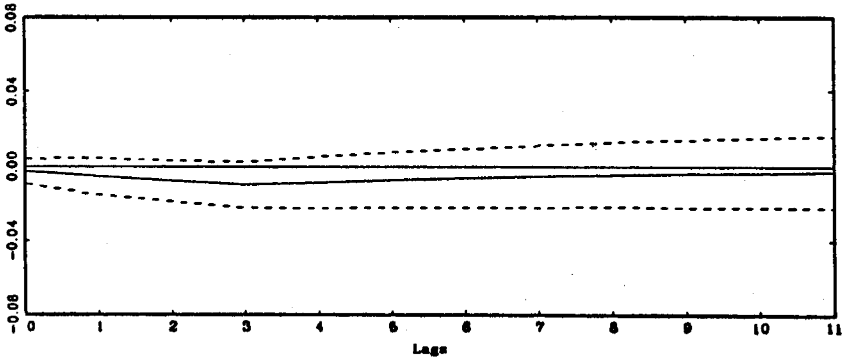


Figure 1.9(wp)f: UK/US e−p+p* response to transitory p−p* shock

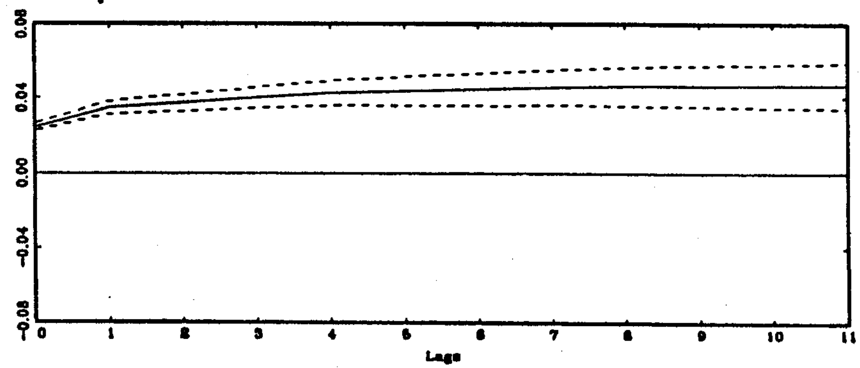


Figure 1.10a: Canada/US p-p* response to permanent p-p* shock

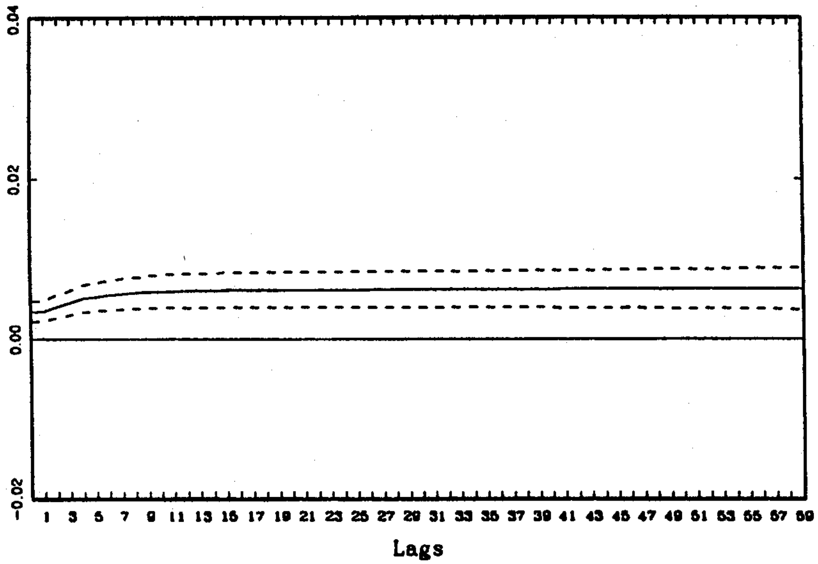


Figure 1.10b: Canada/US p-p* response to transitory p-p* shock

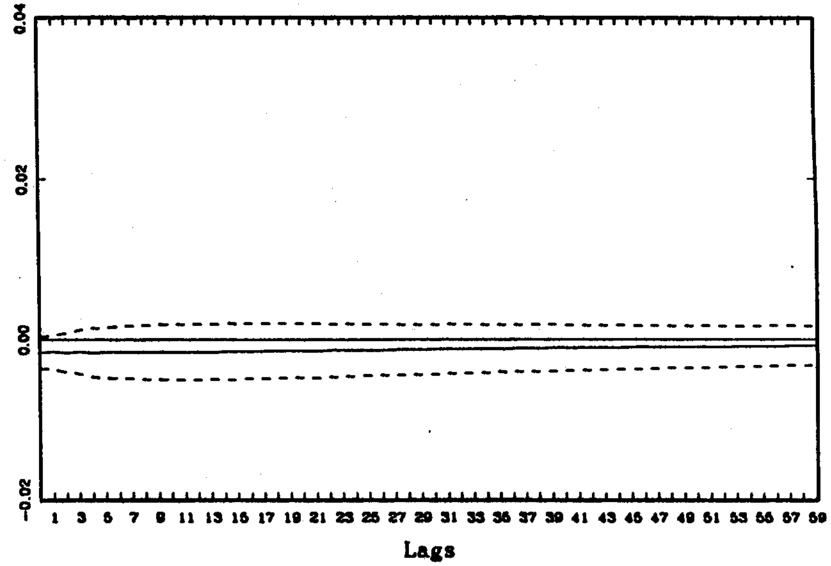


Figure 1.10c: Canada/US e-p+p* response to permanent p-p* shock

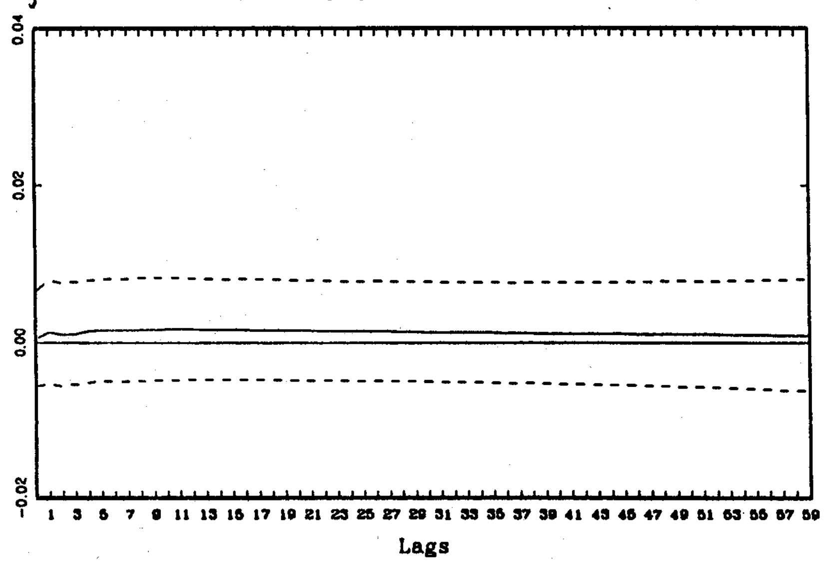


Figure 1.10d: Canada/US e-p+p* response to transitory p-p* shock

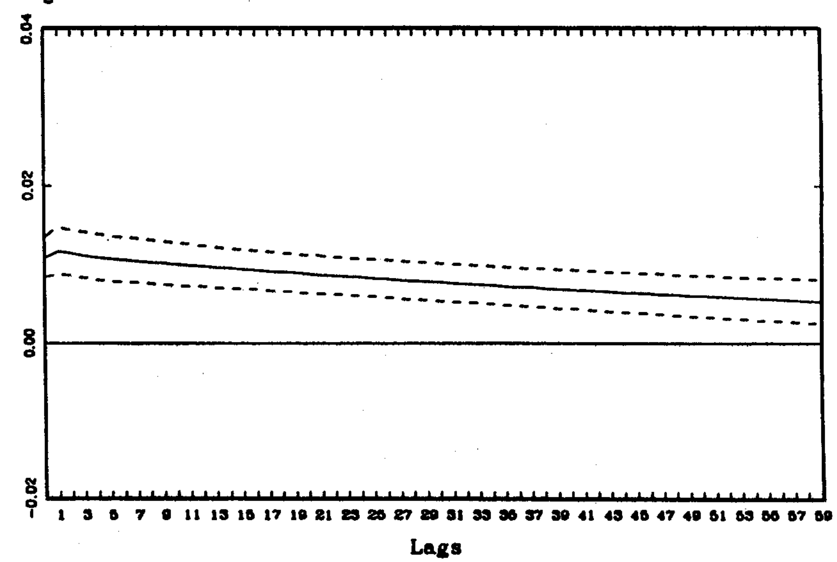


Figure 1.10(wp)a: Canada/US $p-p^*$ response to permanent $p-p^*$ shock

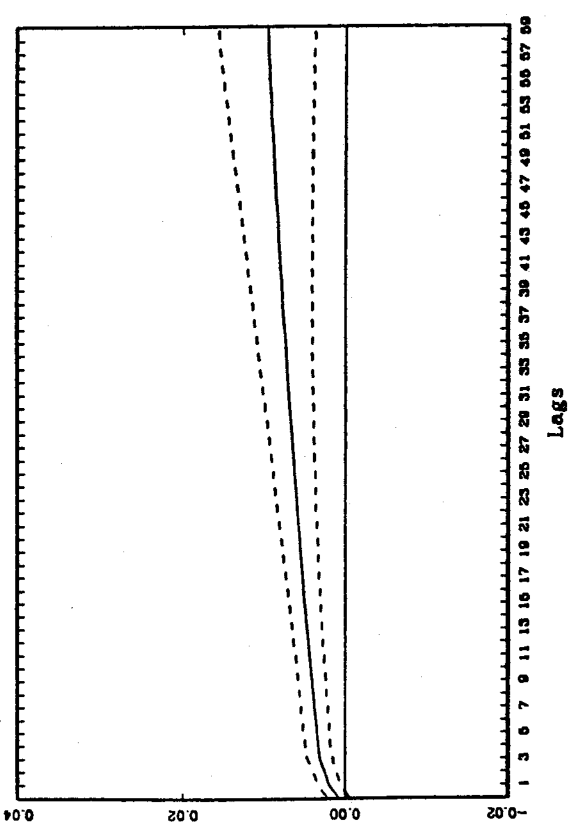


Figure 1.10(wp)b: Canada/US $p-p^*$ response to transitory $p-p^*$ shock

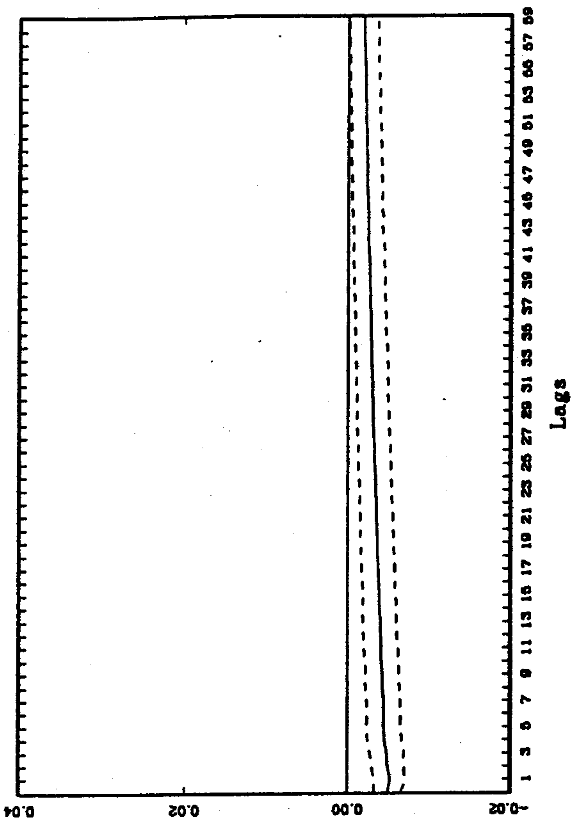


Figure 1.10(wp)c: Canada/US $e-p+p^*$ response to permanent $p-p^*$ shock

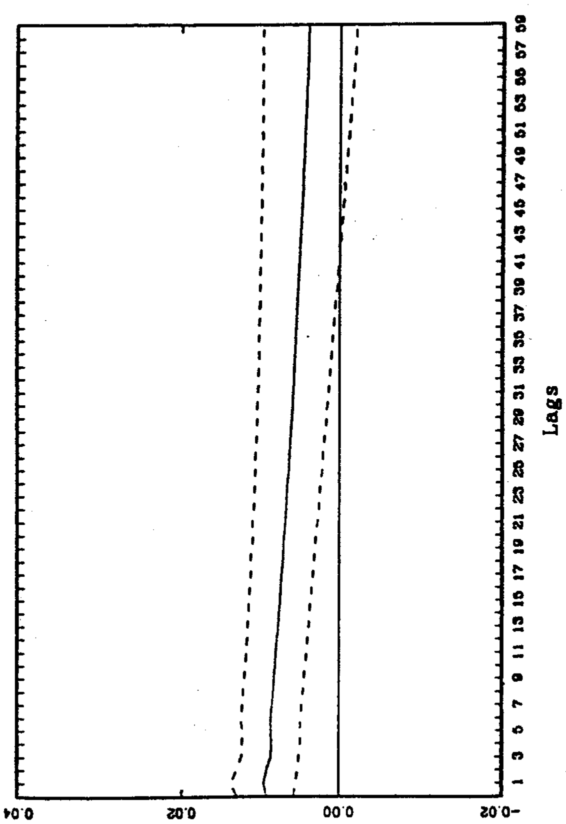


Figure 1.10(wp)d: Canada/US $e-p+p^*$ response to transitory $p-p^*$ shock

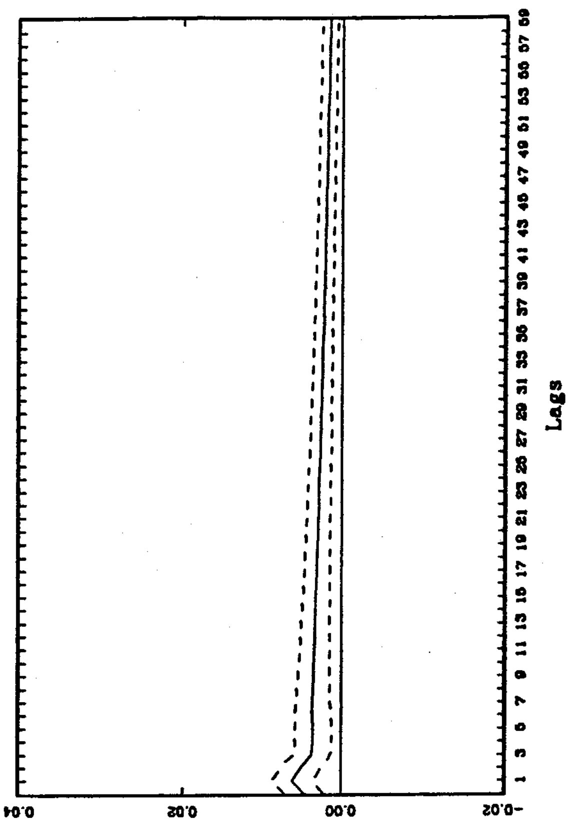


Figure 1.11a: France/US p−p* response to permanent p−p* shock

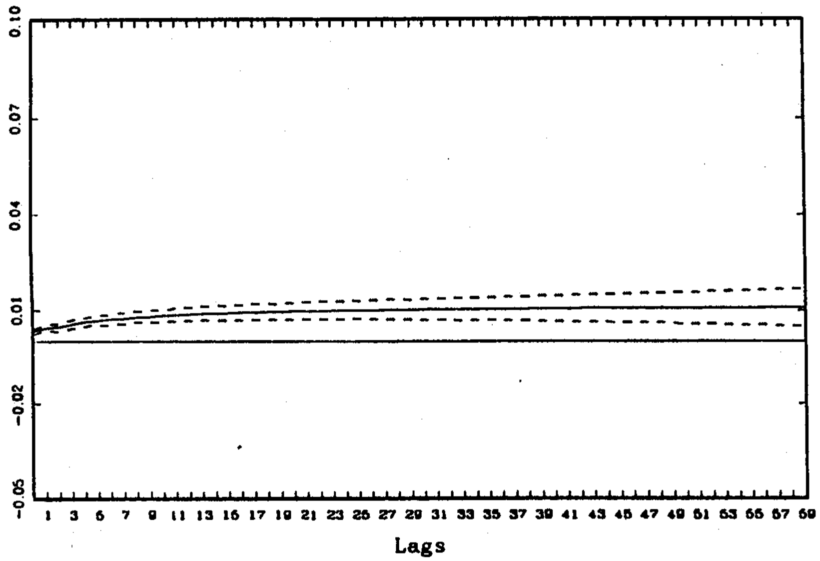


Figure 1.11b: France/US p−p* response to transitory p−p* shock

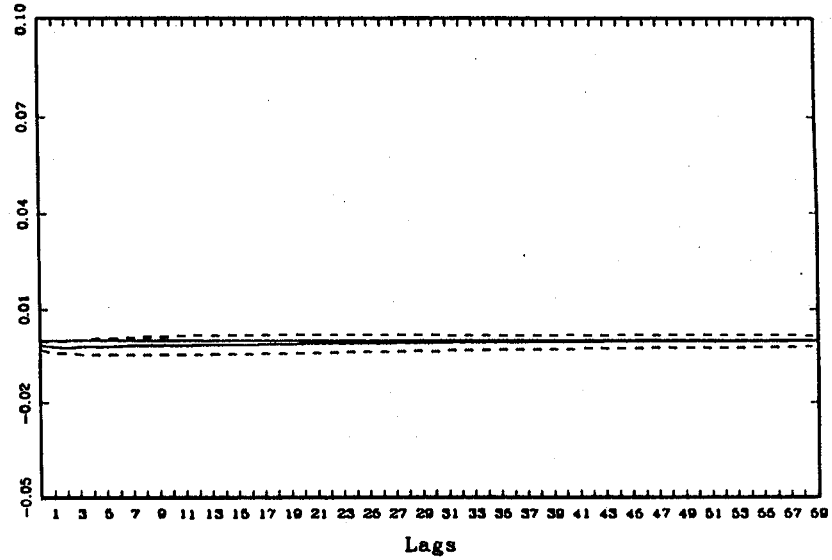


Figure 1.11c: France/US e−p+p* response to permanent p−p* shock

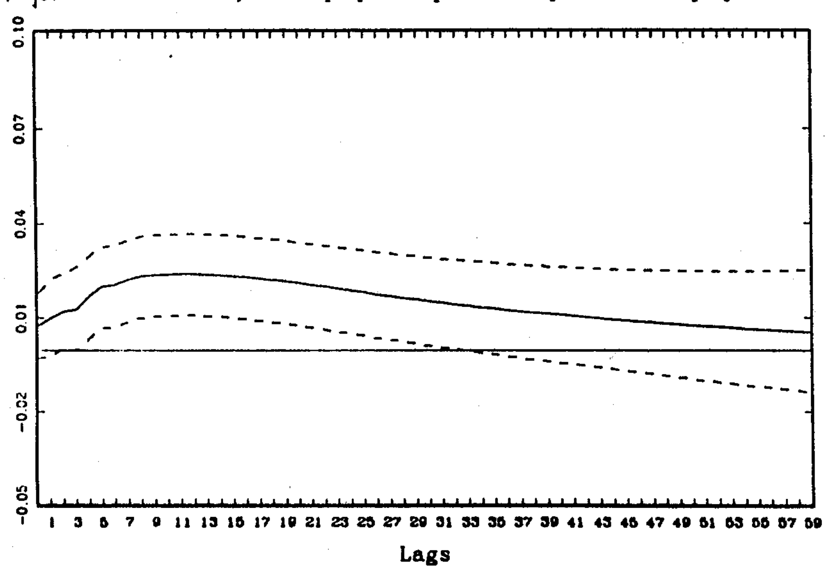


Figure 1.11d: France/US e−p+p* response to transitory p−p* shock

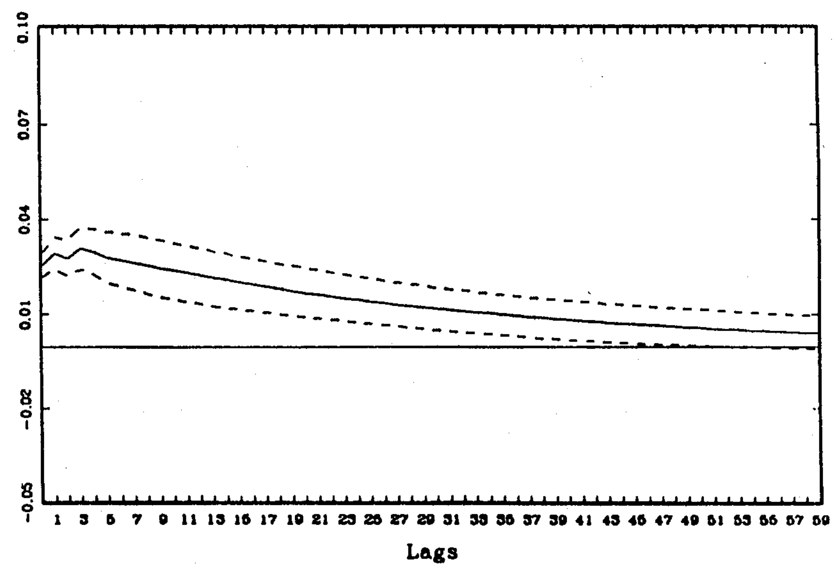


Figure 1.11(wp)a: France/US p−p* response to permanent p−p* shock

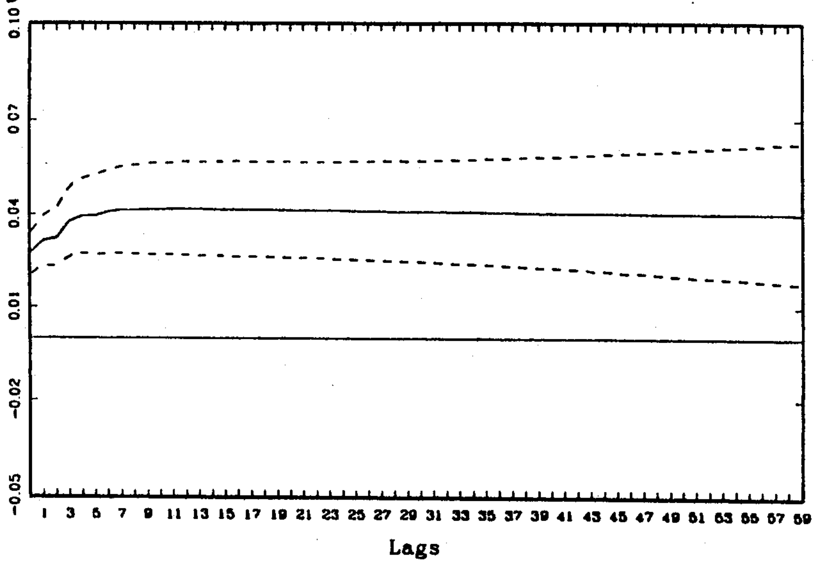


Figure 1.11(wp)b: France/US p−p* response to transitory p−p* shock

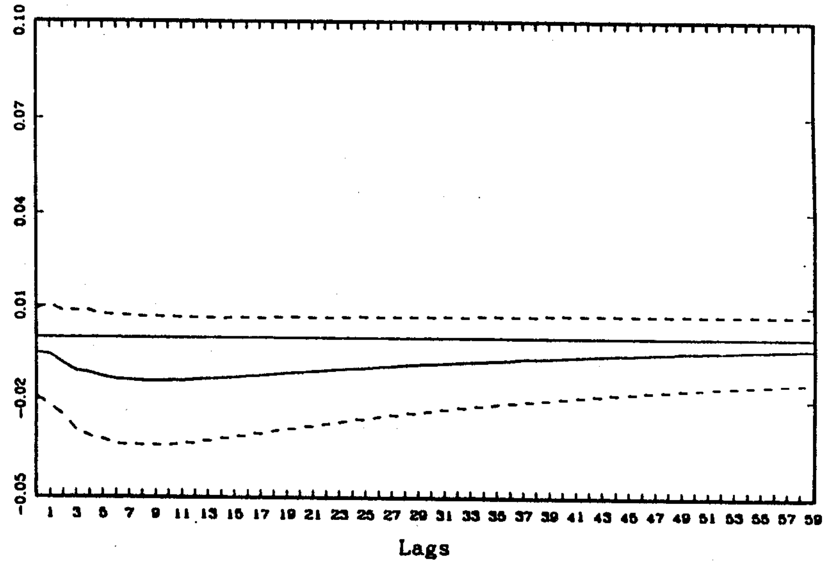


Figure 1.11(wp)c: France/US e−p+p* response to permanent p−p* shock

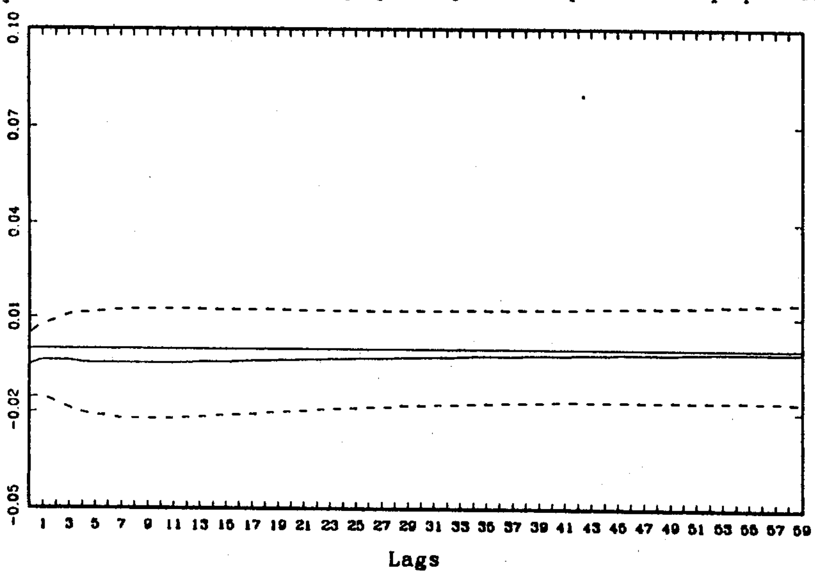


Figure 1.11(wp)d: France/US e−p+p* response to transitory p−p* shock

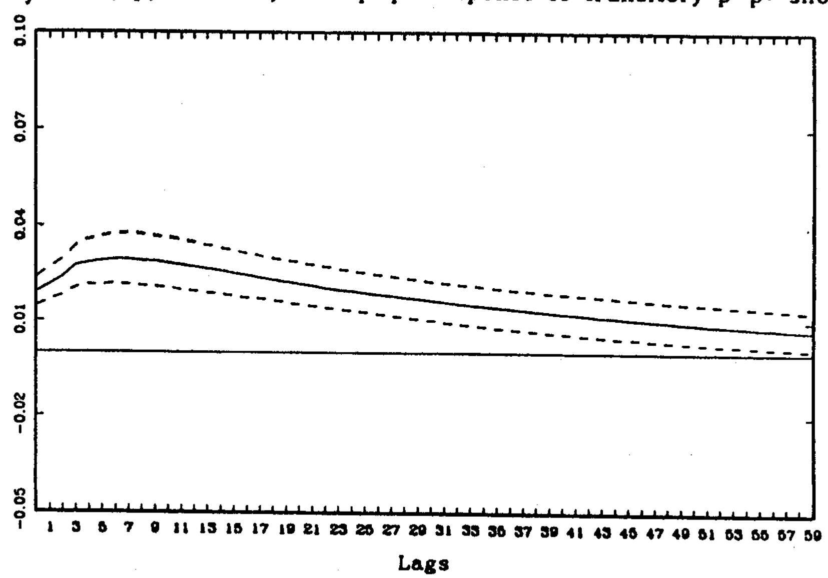


Figure 1.12a: Germany/US p-p* response to permanent p-p* shock

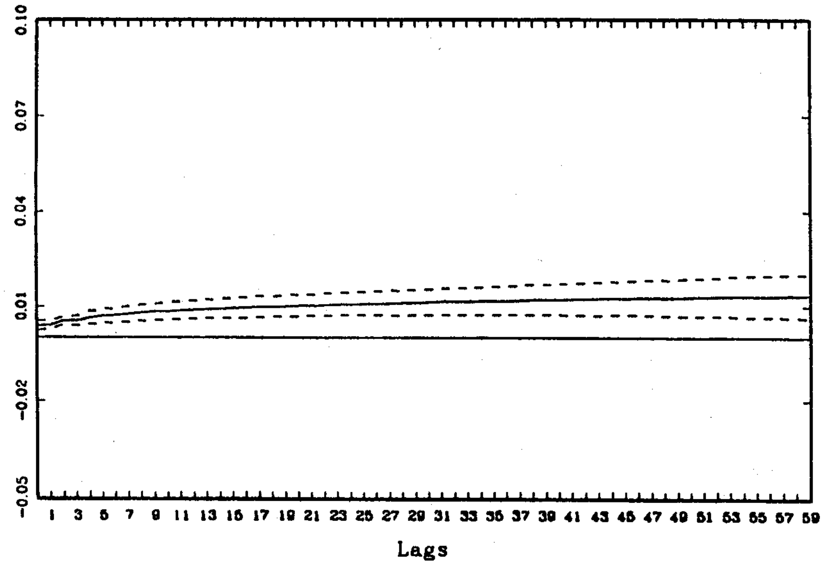


Figure 1.12b: Germany/US p-p* response to transitory p-p* shock

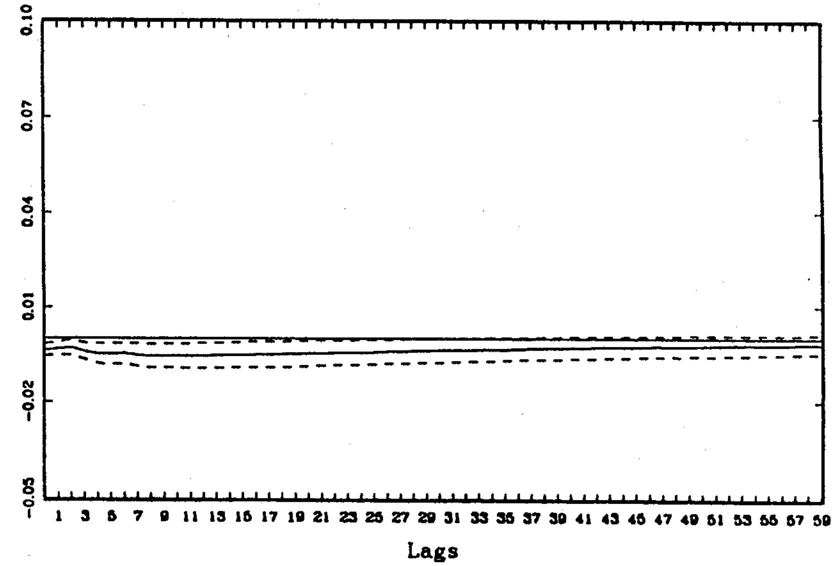


Figure 1.12c: Germany/US e-p+p* response to permanent p-p* shock

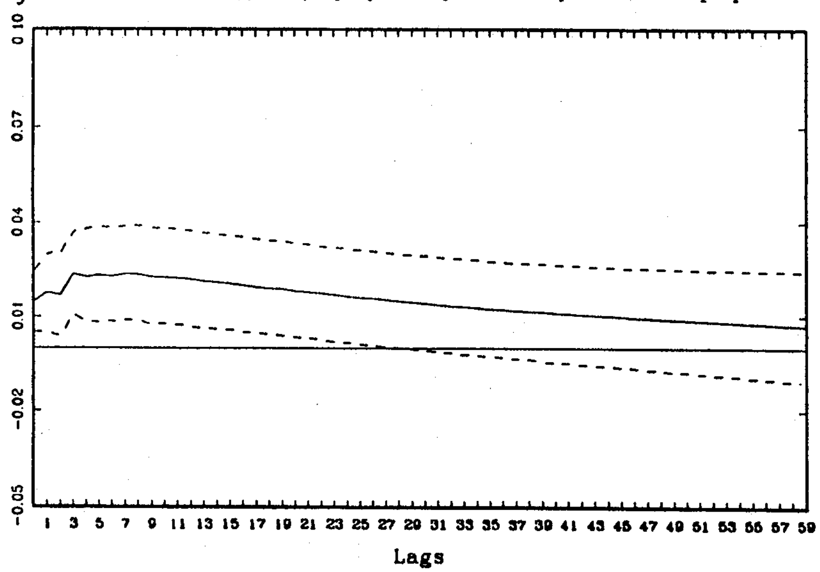


Figure 1.12d: Germany/US e-p+p* response to transitory p-p* shock

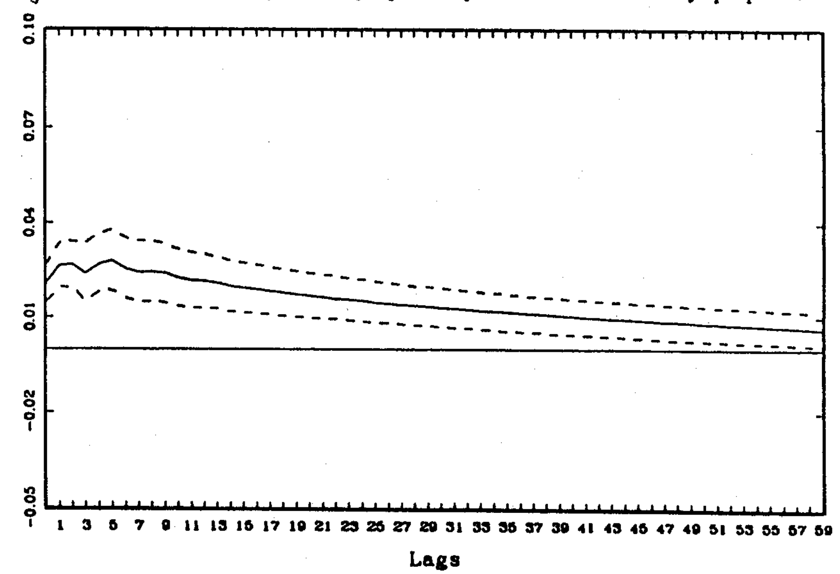


Figure 1.12(wp)a: Germany/US p-p* response to permanent p-p* shock

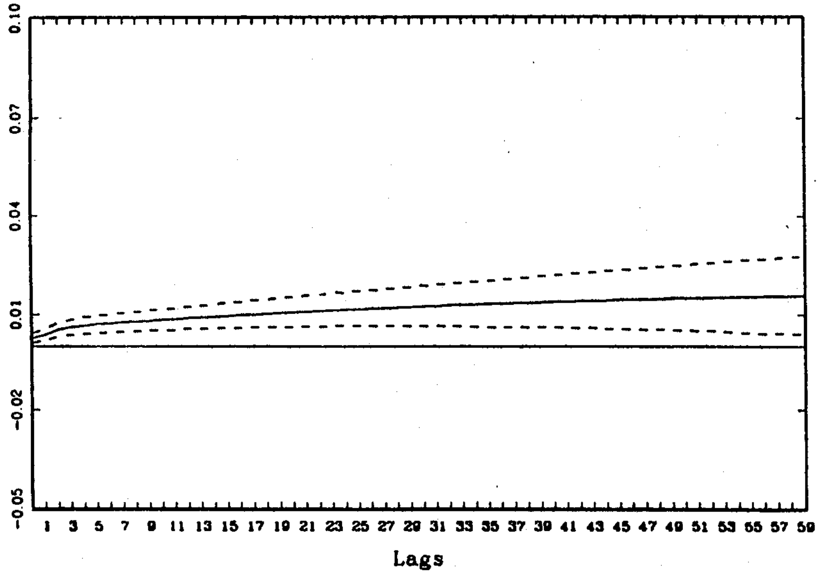


Figure 1.12(wp)b: Germany/US p-p* response to transitory p-p* shock

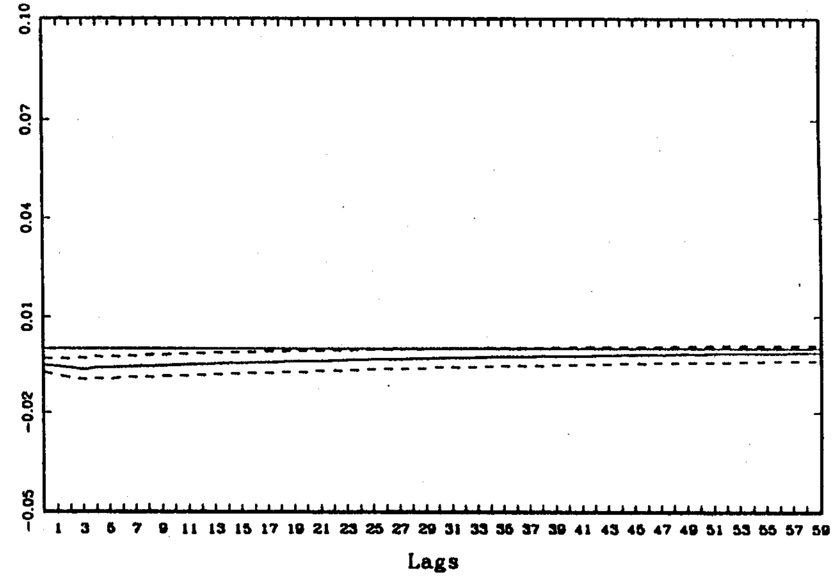


Figure 1.12(wp)c: Germany/US e-p+p* response to permanent p-p* shock

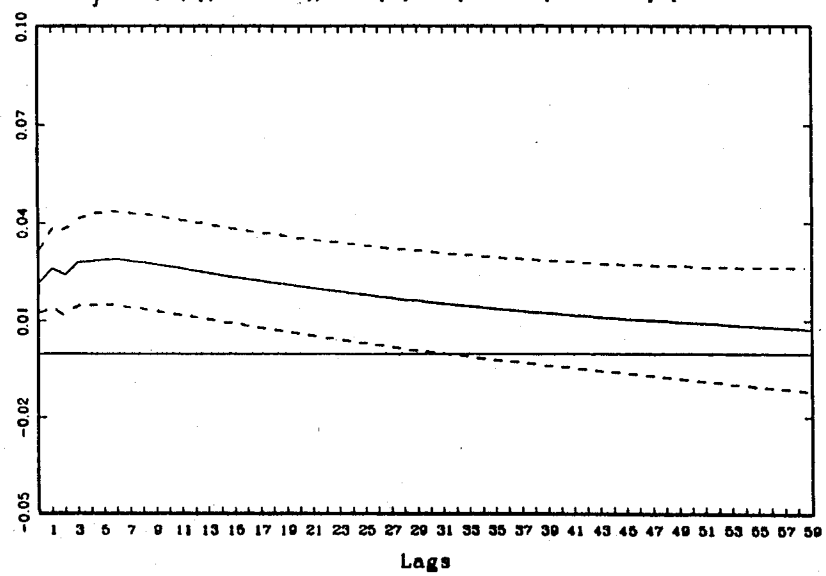


Figure 1.12(wp)d: Germany/US e-p+p* response to transitory p-p* shock

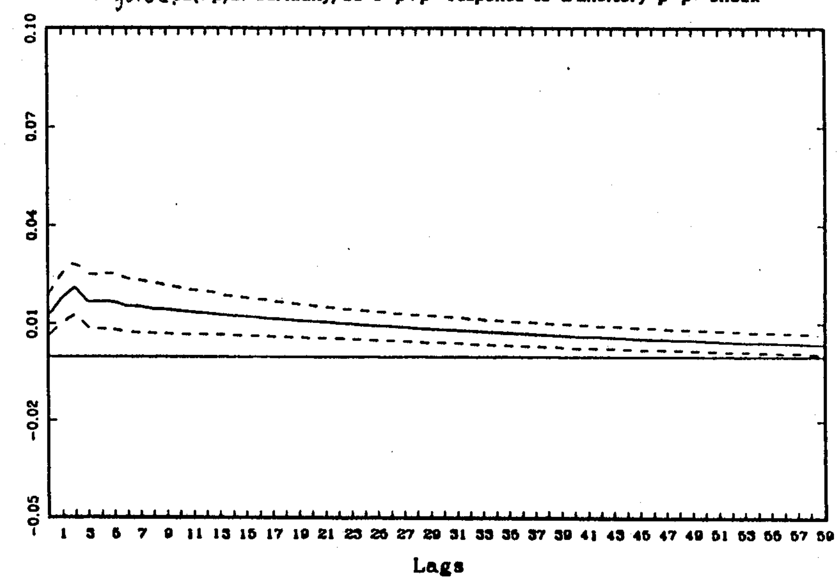


Figure 1.13a: Italy/US p-p* response to permanent p-p* shock

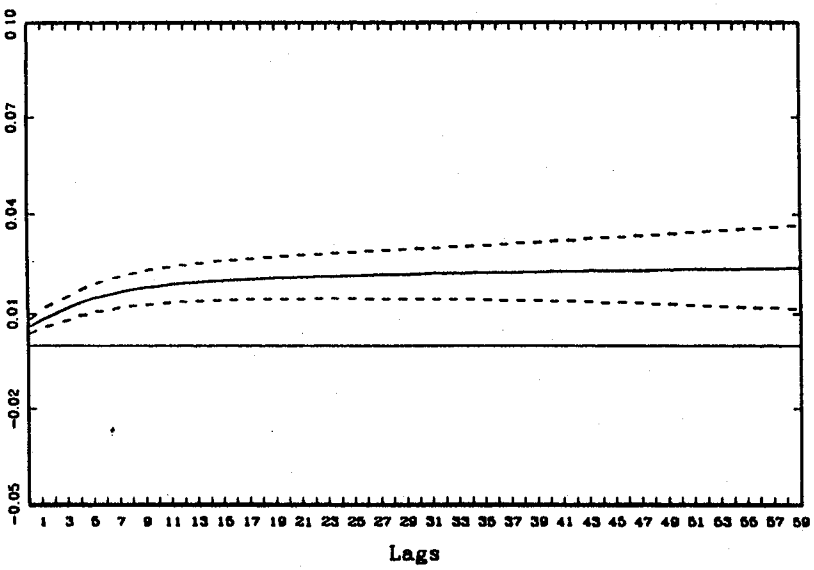


Figure 1.13b: Italy/US p-p* response to transitory p-p* shock

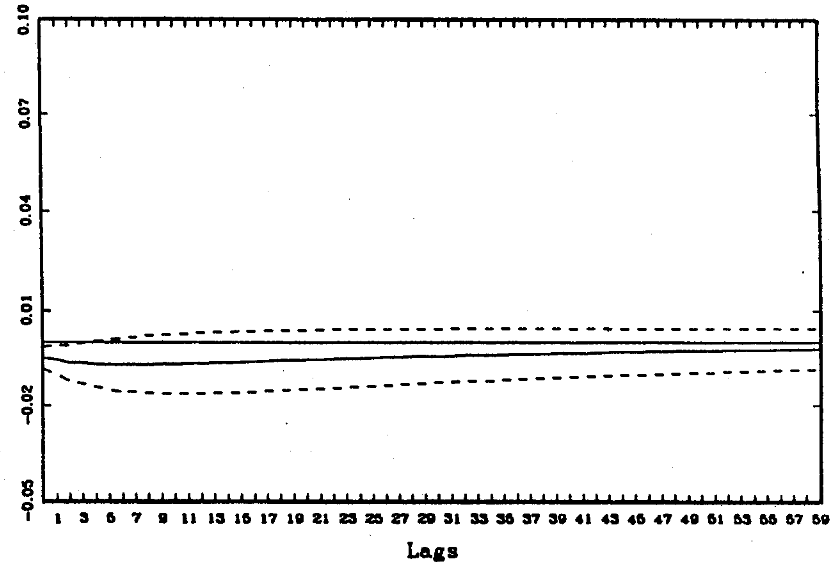


Figure 1.13c: Italy/US e-p+p* response to permanent p-p* shock

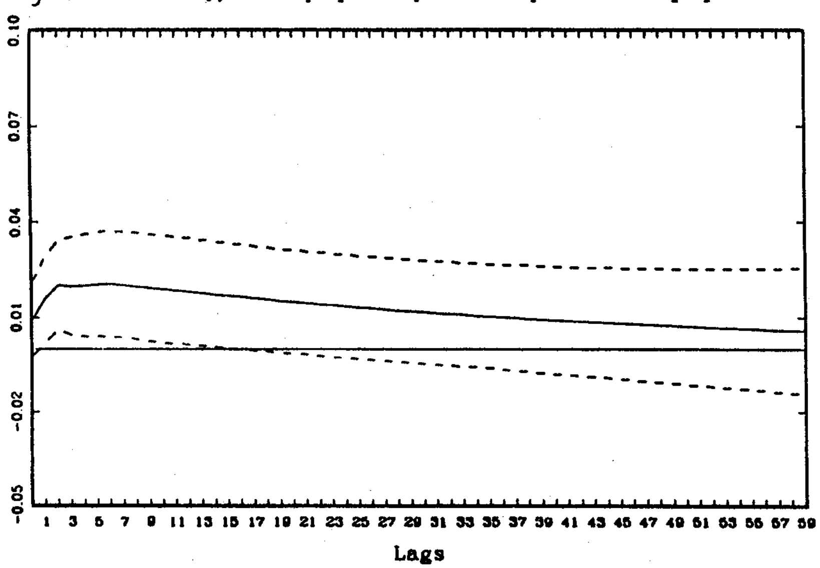


Figure 1.13d: Italy/US e-p+p* response to transitory p-p* shock

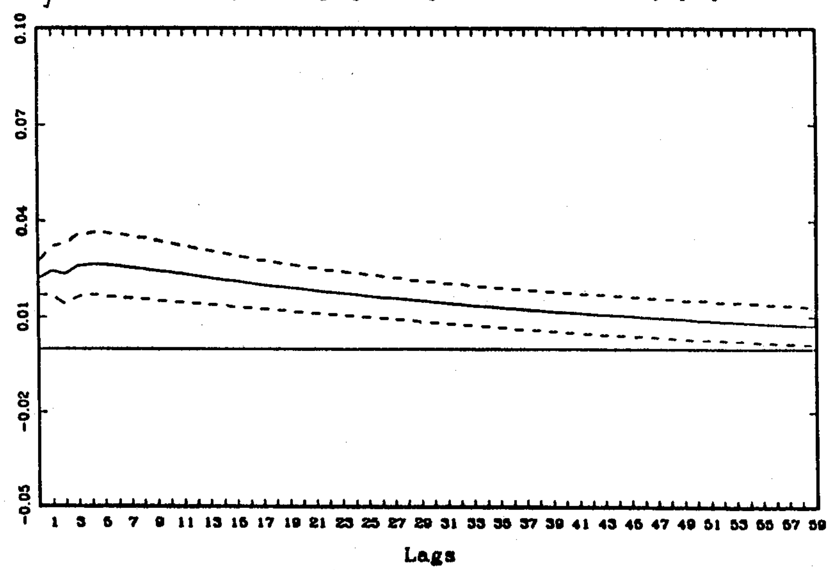


Figure 1.13(wp)a: Italy/US p−p* response to permanent p−p* shock

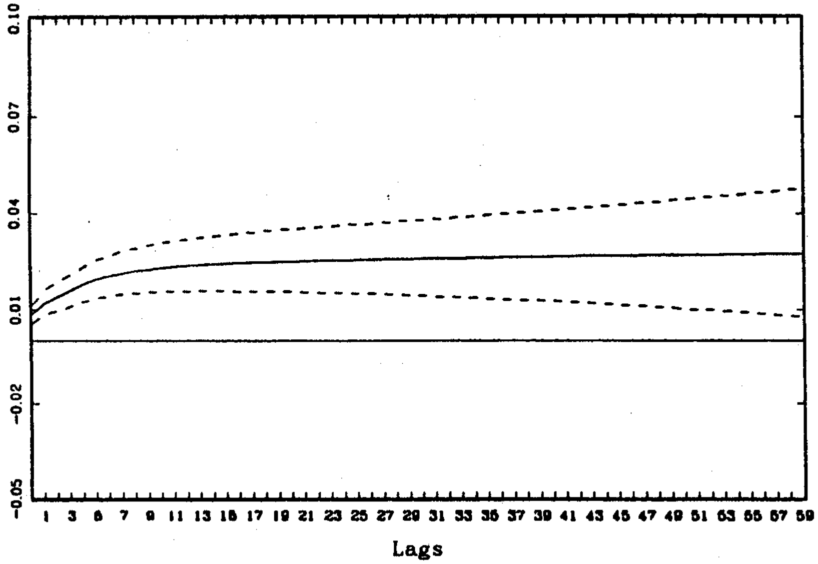


Figure 1.13(wp)b: Italy/US p−p* response to transitory p−p* shock

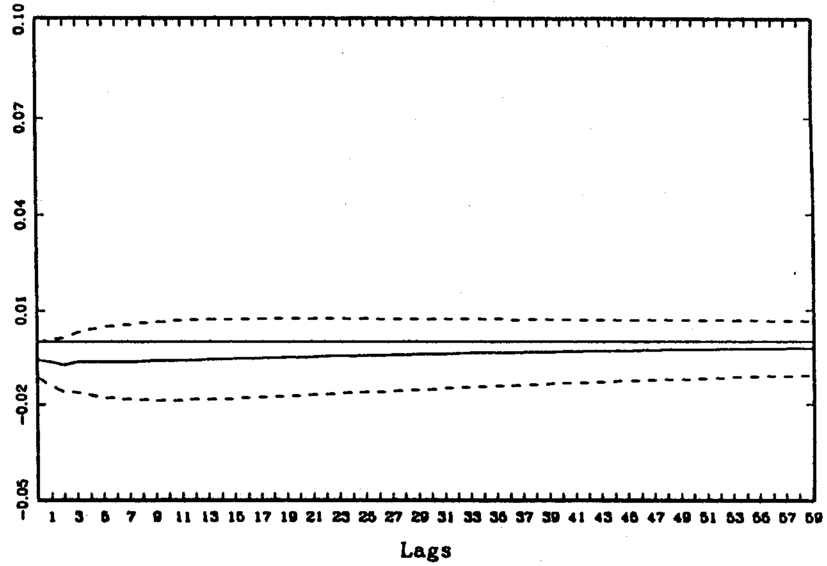


Figure 1.13(wp)c: Italy/US e−p+p* response to permanent p−p* shock

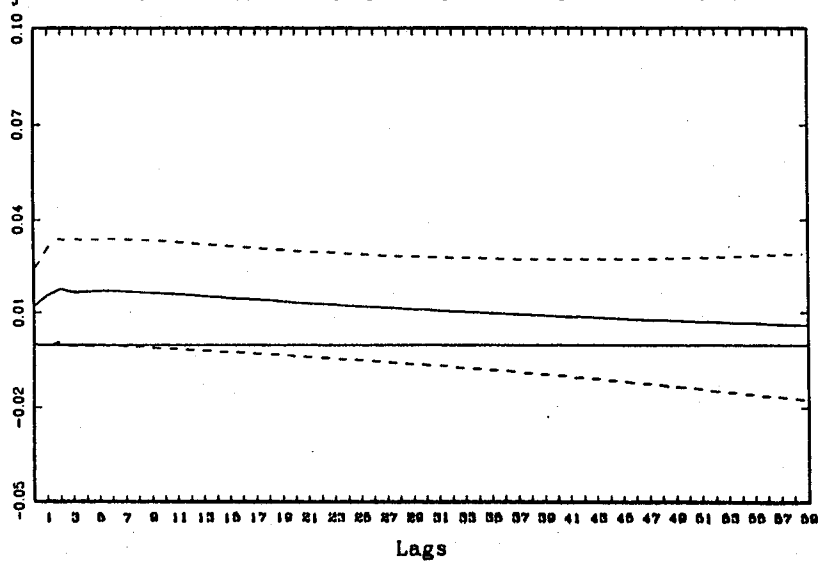


Figure 1.13(wp)d: Italy/US e−p+p* response to transitory p−p* shock

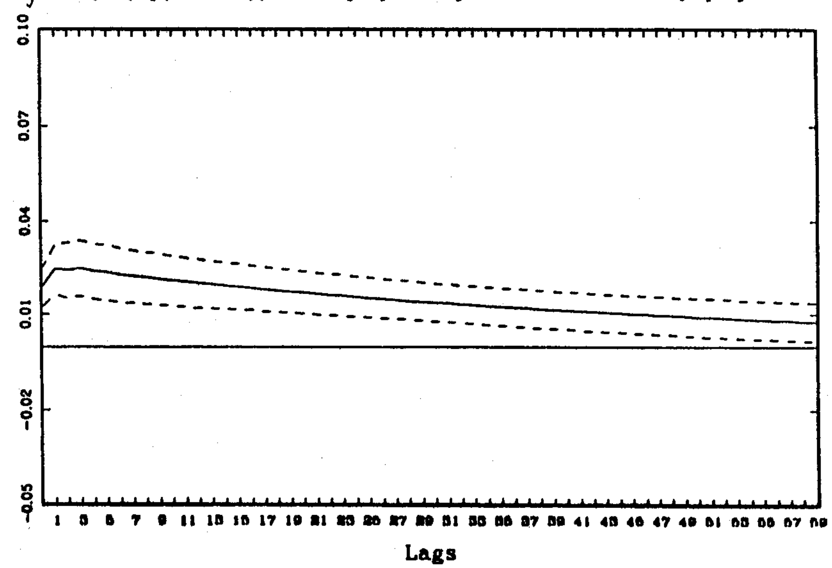


Figure 1.14a: Japan/US p−p* response to permanent p−p* shock

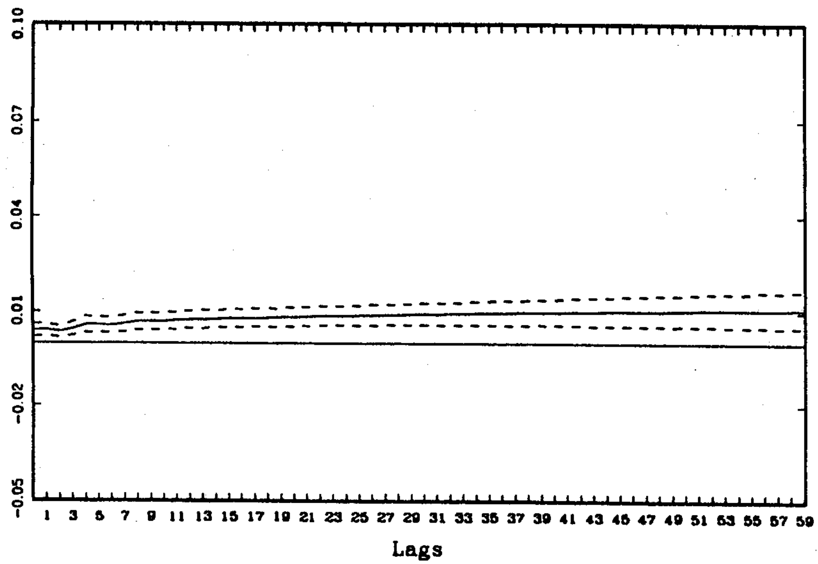


Figure 1.14b: Japan/US p−p* response to transitory p−p* shock

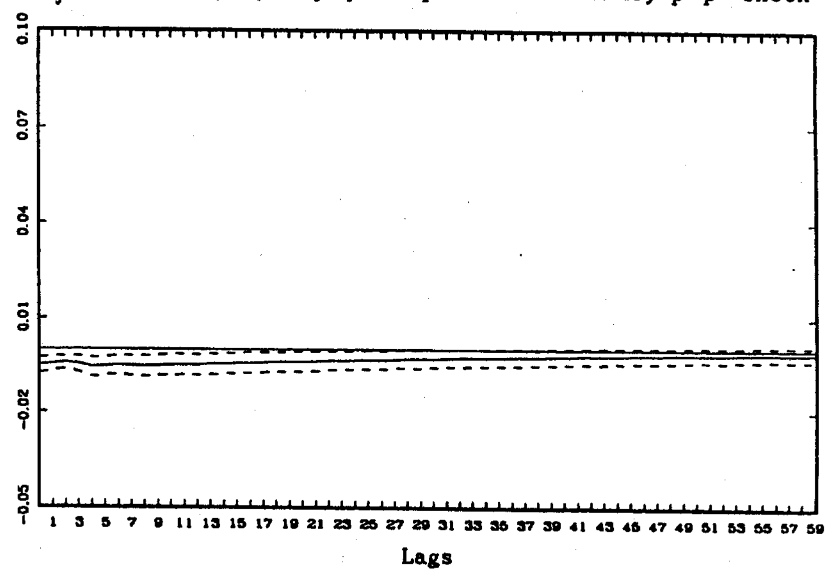


Figure 1.14c: Japan/US e−p+p* response to permanent p−p* shock

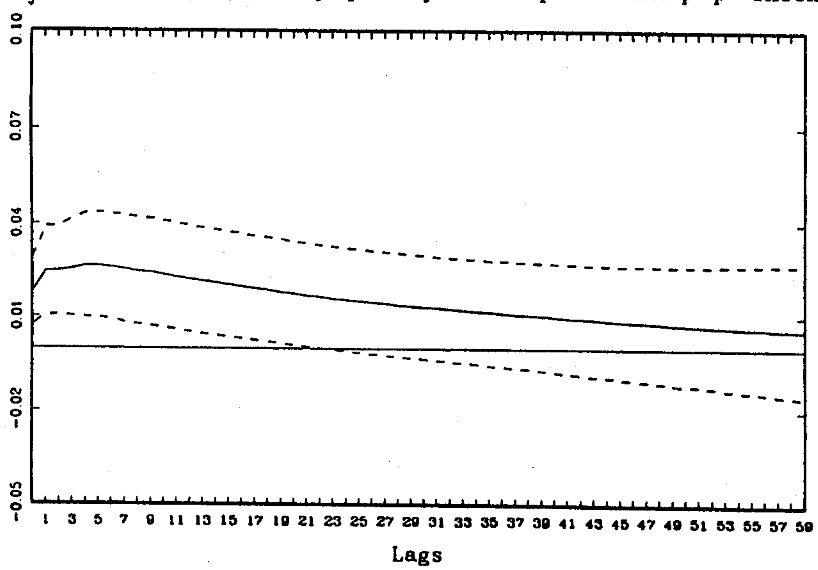


Figure 1.14d: Japan/US e−p+p* response to transitory p−p* shock

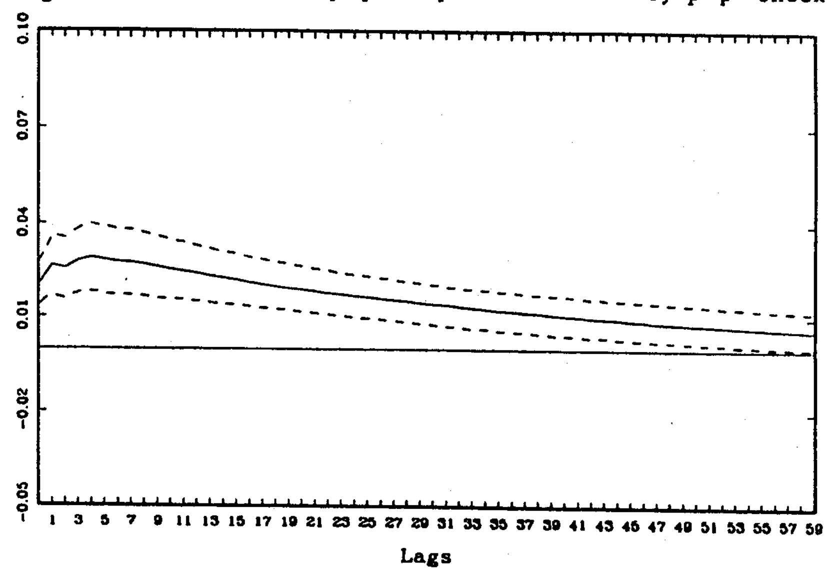


Figure 1.14(wp)a: Japan/US p-p* response to permanent p-p* shock

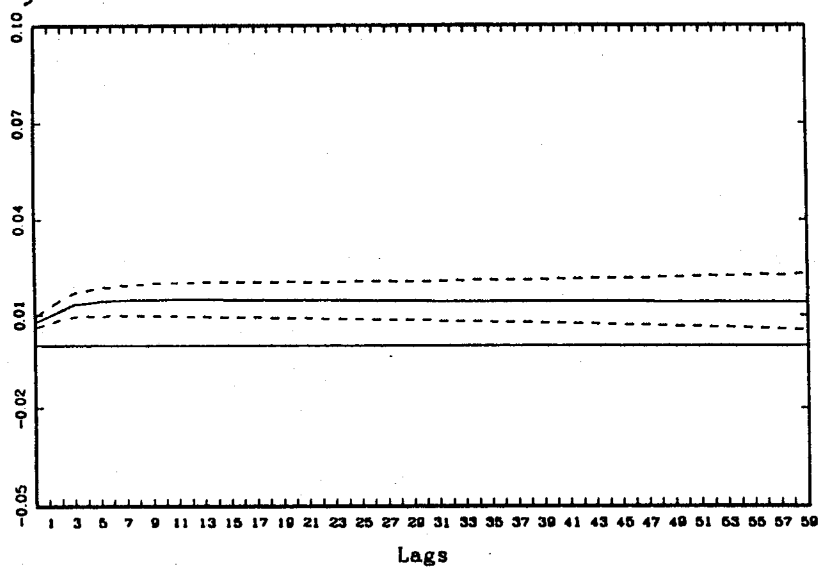


Figure 1.14(wp)b: Japan/US p-p* response to transitory p-p* shock

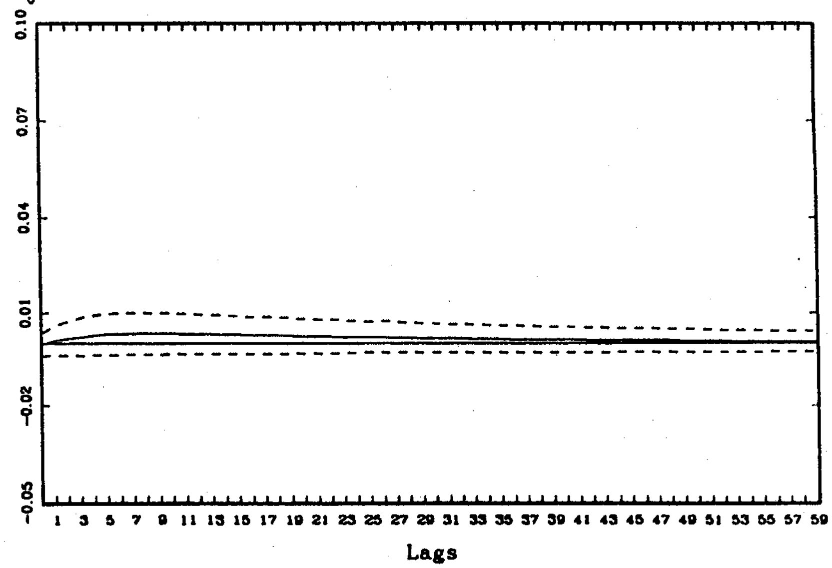


Figure 1.14(wp)c: Japan/US e-p+p* response to permanent p-p* shock

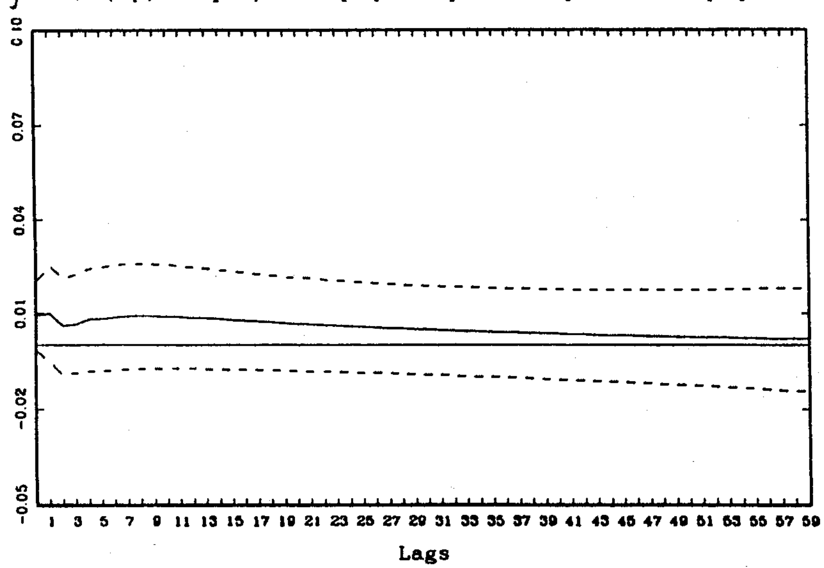


Figure 1.14(wp)d: Japan/US e-p+p* response to transitory p-p* shock

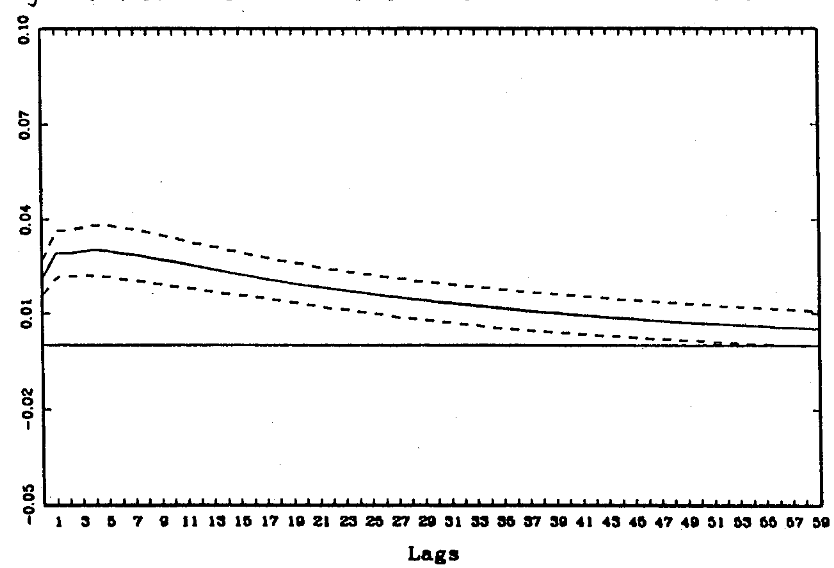


Figure 1.15a: UK/US p–p* response to permanent p–p* shock

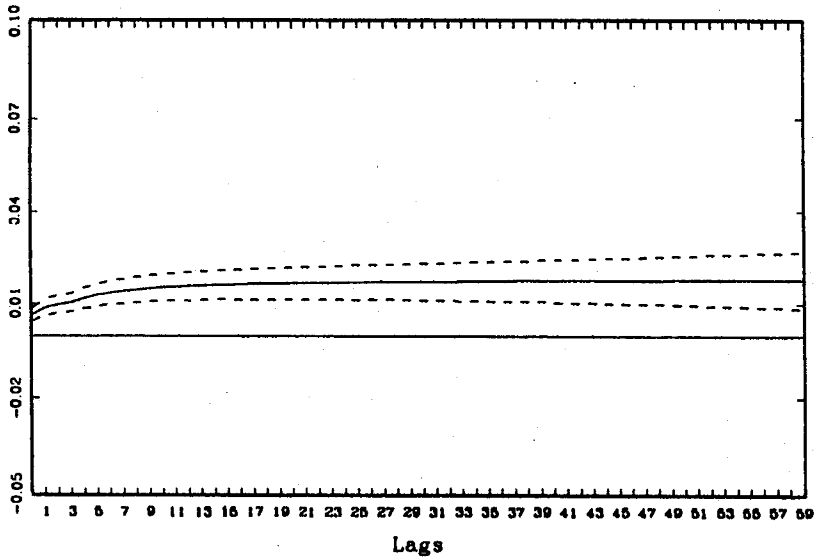


Figure 1.15b: UK/US p–p* response to transitory p–p* shock

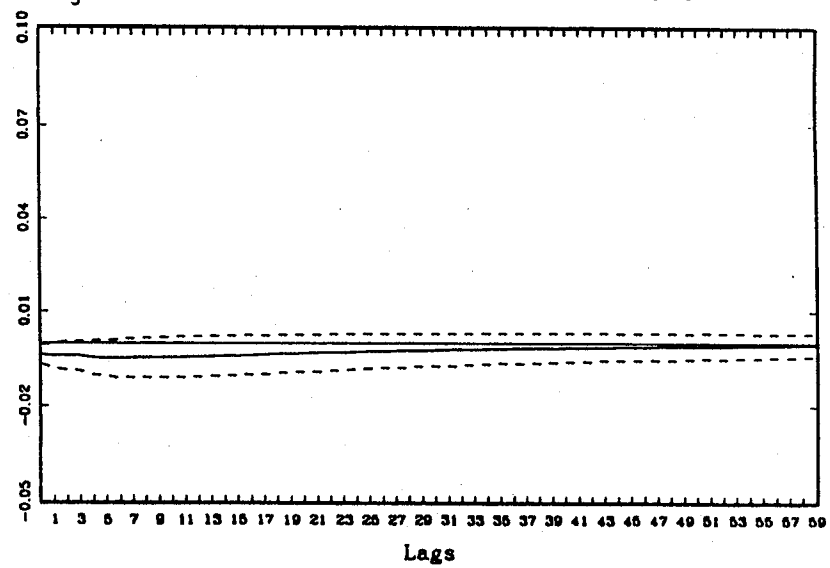


Figure 1.15c: UK/US e–p+p* response to permanent p–p* shock

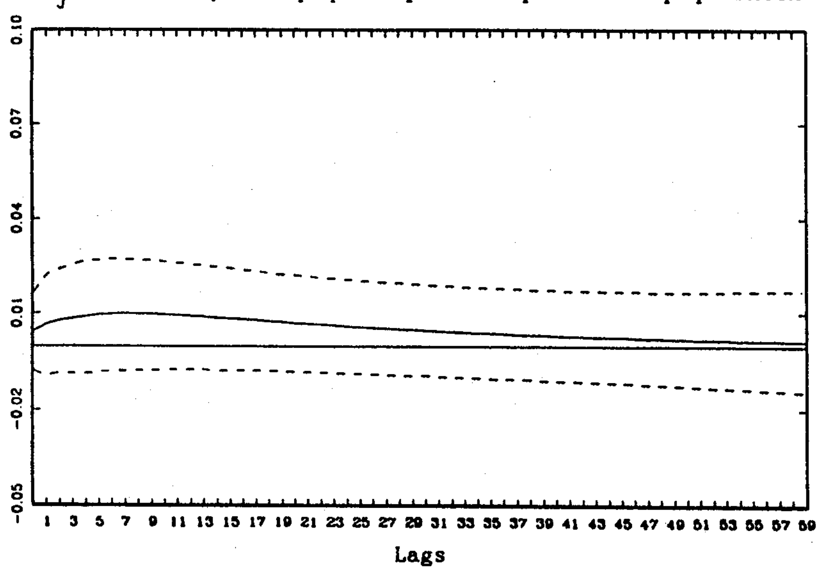
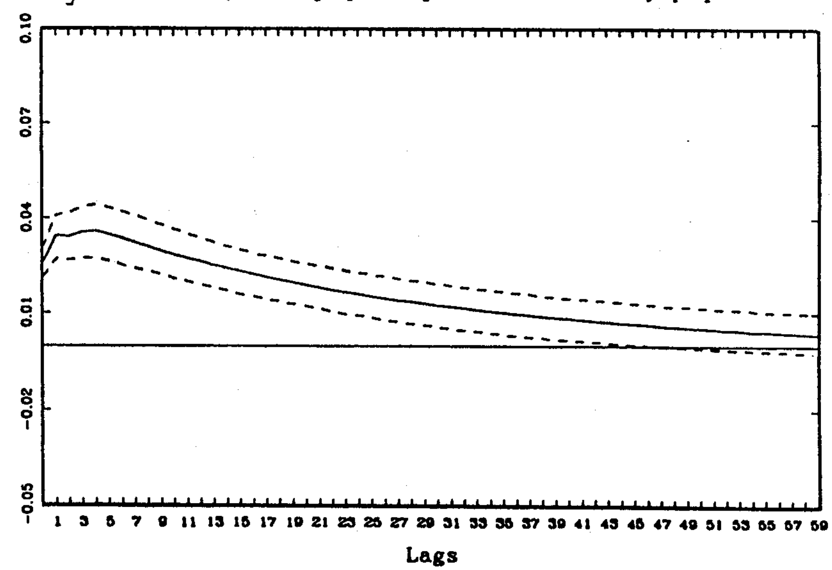


Figure 1.15d: UK/US e–p+p* response to transitory p–p* shock



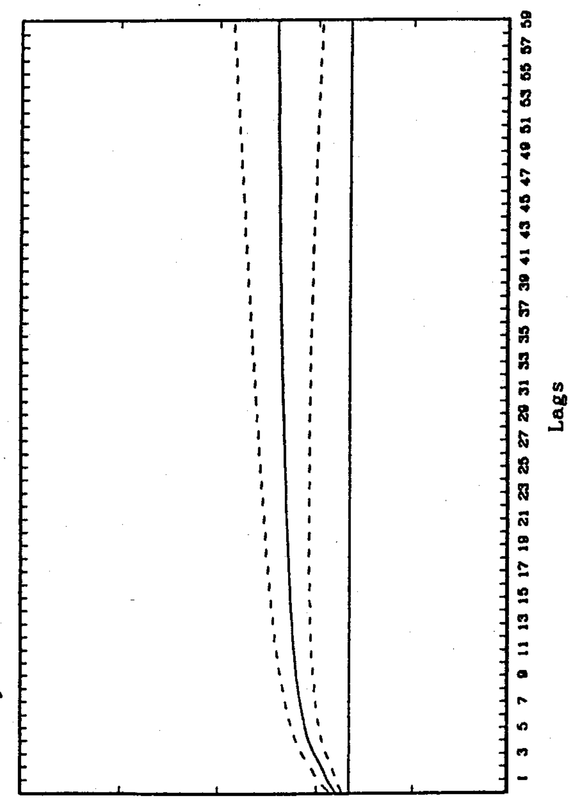


Figure 1.15(wp)a: UK/US p-p* response to permanent p-p* shock

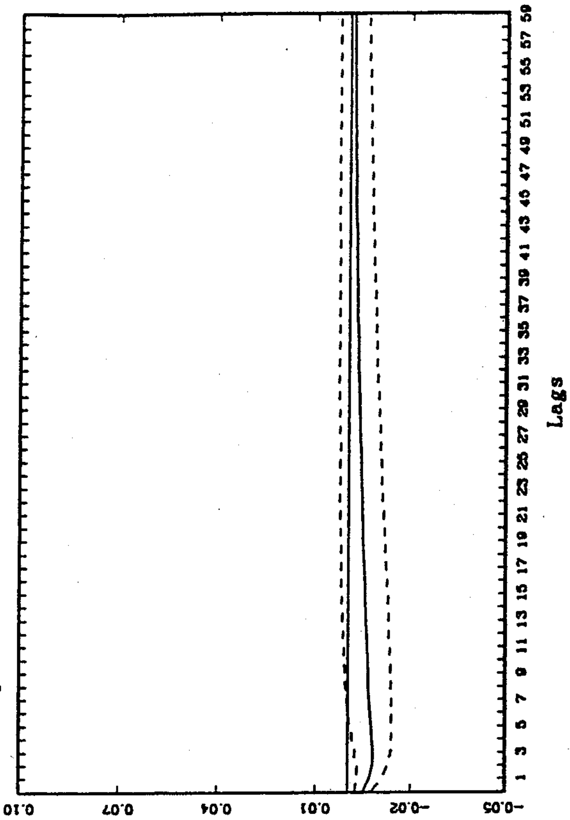


Figure 1.15(wp)b: UK/US p-p* response to transitory p-p* shock

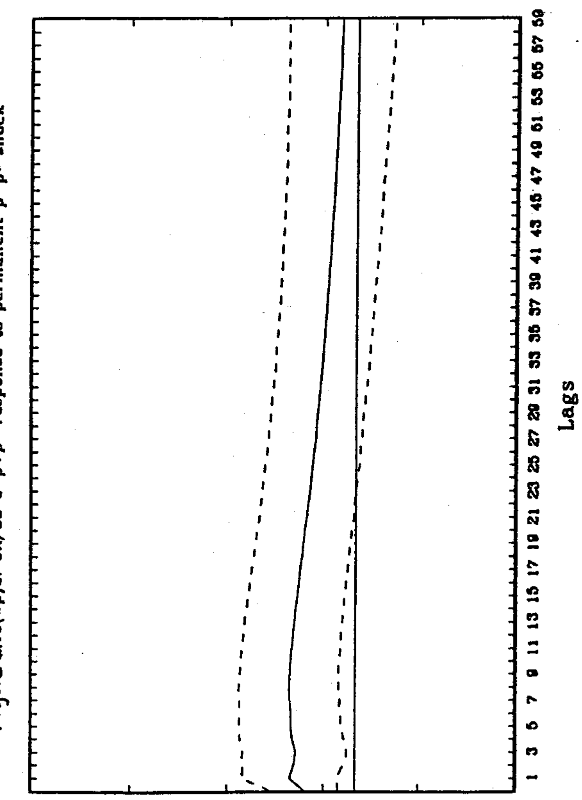


Figure 1.15(wp)c: UK/US e-p+p* response to permanent p-p* shock

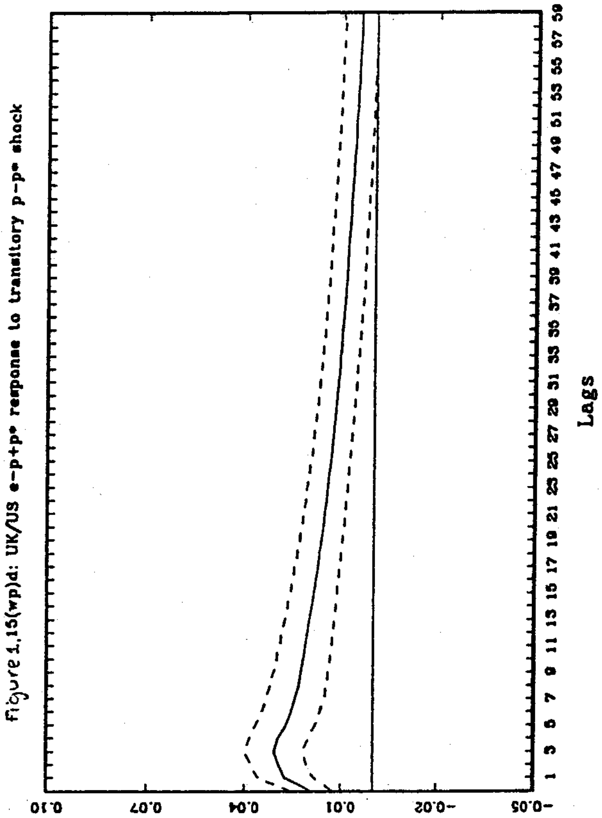


Figure 1.15(wp)d: UK/US e-p+p* response to transitory p-p* shock

2 CHAPTER 2: A Small Open Economy In Depression: Lessons From Canada In The 1930's

2.1 Introduction

The conventional view of the global Depression of the 1930's is that a recession originating in the United States during 1929, and initiated by Federal Reserve stringency, was exacerbated domestically by financial crises following the Stock Market Crash and transmitted internationally through some combination of goods and financial market forces. This view is challenged by coincidence in the timing of output collapse across countries early in 1929, yet it has never been subjected to systematic empirical evaluation and remains the preeminent interpretation of events.

Canada is perhaps the quintessential small open economy, and provides a fertile testing ground for the hypothesis that idiosyncratic U.S. disturbances and their international propagation can account for the global Depression. I test this hypothesis by estimating a small open economy model for Canada in which the U.S. represents the rest of the world. This jointly identifies macroeconomic fluctuations in Canada and the U.S. with realizations from a set of country-specific and international disturbances. My results suggest that the onset, depth and persistence of output collapse in both countries are attributable to permanent output disturbances which are common to the two economies. I find no significant role in the output collapse for monetary, asset market or demand disturbances originating in either the Canadian or U.S. economy.

The experience of the Canadian economy during the interwar period and the remarkable parallels between economic performance in Canada and the U.S. can be seen in Figures 2.1a-2.1f.[1] In each country, real production declined by 30% between 1929 and 1933 and subsequently rose to its 1929 level by 1937. From 1929-1933, private investment fell by 74% and 78% in the U.S. and Canada respectively.[2] The time paths of nominal variables, M1 money stocks and velocities and (wholesale) prices, also exhibit remarkable symmetry. These similarities suggest that the two economies were influenced by similar disturbances that they propagated in similar ways, yet the economic history of each country has emphasized idiosyncratic factors.

The proximate source of the 1929 recession in the U.S. which precipitated the subsequent output collapse is widely held to be the tight money stance that the Fed undertook in 1928 to prevent gold outflows following the Poincare deflation and to stem speculation in financial markets (Hamilton (1987) and Temin (1993)). Field (1984) and Hamilton (1987) argue that the contractionary effects of this policy were exacerbated by rising demand for transactions balances to finance the excep-

[1] For data sources and definitions see Table 2.1.

[2] See Urquhart and Buckley (1965) and the U.S. Department of Commerce (1975).

tional volume of asset trades, while Temin (1976) and Romer (1990) propose that an important contributing factor was the collapse of domestic consumption. Temin asserts that an 'inexplicable' decline in autonomous expenditure during 1929 is the source of this collapse in contrast to Romer's (1990) emphasis on the decline *induced* by future income uncertainty following the Stock Market Crash in October. Friedman and Schwarz (1963) attribute the *persistence* of the U.S. Depression to monetary collapse following the Fed's misguided base contraction policy of 1930 and aggravated by the effects of banking crises throughout the early 1930's. Their emphasis on the demand effects of the attendant rise in real interest rates is disputed by Bernanke (1983) who argues that only the investment and aggregate supply effects engendered by the banking crises can explain the persistence of output collapse. Bernanke asserts that the loss of bank intermediated credit raised the cost of credit intermediation and so investment and Cecchetti and Karras (1992), using a similar econometric methodology to that applied in this paper, present some empirical support for this hypothesis.

The onset and persistence of the global Depression is frequently attributed to international transmission of real and nominal U.S. disturbances through strict nominal parity relations under the gold exchange standard, at least until 1931. Temin (1991), Eichengreen (1992), Romer (1993) and Temin (1993) all support this view of the transmission mechanism. Bernanke and James (1991) and Calomiris (1993) argue that imported *monetary* contractions from the U.S., especially, explain the duration as well as the onset of the worldwide output collapse. Debtor defaults associated with unanticipated 'debt-deflation', and the supply-side effects of attendant bankruptcies and banking crises can account for international persistence of a transmitted monetary contraction. Others have emphasized the role of declining export markets and capital flows in highly integrated goods and capital markets under the fixed exchange rate as the important source of transmission of the U.S. output collapse (Kindleberger (1984)). Yet typically, the economic history of Canada and Europe stresses significant country-specific factors with potential to generate recession in the late 1920's quite independently of the U.S. collapse.

Safarian's (1959) informal Keynesian analysis remains the leading interpretation of events in Canada. Safarian emphasizes not only Canada's dependence on primary commodity exports and peculiar vulnerability to the collapse of world trade, but also declining investment opportunities in the domestic economy. These reflected overexpansion during the 1920's in the new resource intensive industries, such as pulp and paper, exacerbated by the completion of Western settlement. He notes that while Canadian exports had recovered their 1929 level by 1937, investment remained at half its 1929 peak at that date. Similarly, Green and Sparks (1988) present empirical evidence to suggest that, while both the onset and severity of the Depression in Canada are explicable by the decline in exports, the initial domestic downturn is attributable to a reduction in the autonomous export component. This is independent of changes in U.S. income and the terms of trade, implying that the export collapse did not simply reflect transmission of disturbances from the U.S.

Haubrich (1990) examines the role of financial market disruptions in exacerbating the Canadian Depression. The absence of bank failures in Canada, despite substantial financial market disruption and in contrast to the U.S. experience, allows Haubrich to isolate their contribution to the output collapse. He finds that neither debt level nor commercial failure measures can explain the decline in Canadian output implying that bank failures *per se* were the financial market source of output fluctuations in the U.S. Haubrich also finds little explanatory power for U.S. monetary aggregates or reduced export volume in accounting for Canadian output fluctuations.

My objective in this paper is to evaluate systematically these competing views about the open economy experience of the Great Depression using data from the interwar Canadian macroeconomy. In particular, I test whether the transmission of idiosyncratic U.S. disturbances can explain the output collapse in Canada, whether shocks of domestic origin were more important, or whether the Depression in Canada and the U.S. originated from a common source. Using monthly data on output, prices and money stocks for the interwar sample 1925-1940, I estimate a small open economy model for Canada in which data from the U.S. represent the rest of the world. Specifically, I identify a structural moving average representation which is consistent with the long-run equilibrium and dynamic properties of such a model. The representation decomposes output fluctuations in Canada into sources due to five fundamental disturbances.

First, I identify a permanent real output shock which is common to the two economies. This drives the stochastic trend in both output series, permanently affects all of the variables in the empirical model and is interpretable as a supply shock - the result of disturbances to the level of resources and to technology. Second, a permanent nominal shock to the U.S. money stock is identified which I interpret as originating in U.S. monetary policy and which is inherited by the Canadian money stock under the fixed exchange rate regime. This permanent shock to money stocks is also reflected in the permanent component of prices for both economies but has no long-run output effects. Third, I find a permanent common asset market (velocity) disturbance which generates additional permanent shocks to prices in both Canada and the U.S. but is not reflected in output or monetary fluctuations. The fourth disturbance is a purely transitory U.S. shock, which I associate with real demand disturbances, and the fifth an idiosyncratic Canadian shock, which may incorporate purely transitory real and monetary shocks originating in the domestic economy.

The empirical results are stark, although their interpretation is less so. From 1929-1936 the twelve month ahead forecast error in Canadian output is almost entirely due to the common permanent output shock. Similarly, the level of Canadian output at each point in time is almost exclusively attributable to the cumulative effects over time of this disturbance. Equally striking is the remarkable symmetry of the decompositions for Canadian and U.S. output fluctuations. While the velocity and money supply shocks explain a significant component of the price deflation and monetary contraction for both economies, and the transitory 'demand' shocks can explain some output fluctuations in Canada in the pre and post Depression sample, the onset, depth and duration of the Depression in both economies is accounted for by the effects of the common permanent output disturbance. The global Depression is interpretable as an international 'collapse in trend' event.

This result has implications for analyses of the Depression in both Canada and the U.S. It presents a challenge to theories that emphasize the role of the 1928 U.S. monetary contraction in the onset of the U.S. Depression and its transmission to other economies through the Gold Standard. I find that although there were significant negative money supply shocks in early 1928 they do not explain the fall in U.S. or Canadian output in 1929. This does not prohibit an important role for monetary contraction in sustaining the output collapse however. While the identified money supply shocks are insignificant for output fluctuations in both economies throughout the Depression, the money stock responds endogenously and significantly to the permanent output shocks. Consequently, I cannot rule out a role for the induced monetary contraction in aggravating the (international) output collapse. Additionally, the large supply shocks after 1930 which I identify must reflect any unanticipated permanent effects for output due to the financial crises, implying a potentially important role for credit in the supply collapse.

That the onset of the Depression is attributable to permanent 'supply' shocks is consistent with considerable historical evidence of secular change in both the Canadian and U.S. economies. For example, Wright (1990) argues that from 1879 to 1928 U.S. industrial success was founded on extraction of abundant supplies of industrial minerals. By 1940, this was no longer the case implying a dramatic change in the structure of American industry. Bernstein (1987) argues that the U.S. Depression reflected long-term secular change caused by rising income levels during the 1920's. He shows that patterns of consumer demand and, consequently, labour demand and investment shifted as rising income levels promoted industry more heavily oriented to consumer than producer goods. Both arguments suggest a role for secular change in generating output fluctuations in the 1930's. My results are also consistent with Fisher's (1933) argument that the decline in actual and expected productivity in the late 1920's induced a drop in investment demand, sufficient pessimism to engender the Stock Market Crash, and effects for the capital stock which took several years to correct. Safarian's explanation of the Canadian Depression experience, as the outcome of overinvestment in the growth sectors of the economy during the early 1920's, provides a complementary account of a secular output collapse in Canada.

These structural factors are potentially continent-wide, if not global, and can rationalize the commonality of the identified negative supply disturbances which may either have been synchronous across economies or have rapidly diffused across geographic boundaries.

The remainder of the paper is organized as follows. Section 2.2 presents a small open economy model which is consistent with theoretical frameworks employed in previous analyses of the Great Depression in Canada and Section 2.3 develops an empirical representation of this model. Section 2.4 evaluates the consistency of the interwar data with the long-run properties of my open economy model and Section 2.5 shows how these long-run, and also some dynamic, implications of the theoretical model are imposed to identify the empirical representation. Section 2.6 presents the estimation results and Section 2.7 concludes with some interpretations.

2.2 A Small Open Economy Model

2.2.1 Overview

Canada is modeled as a small open economy on a fixed exchange rate with the rest of the world in which goods and capital markets are internationally integrated and capital is mobile. Consequently, although the Canadian economy is too small to impinge on economic conditions in the rest of the world, both domestically originating disturbances and shocks in the rest of the world can effect domestic fluctuations. These fluctuations cannot be offset by Canada's monetary authorities with autonomous policy actions since the domestic money supply is pinned down by the fixed exchange rate commitment.

This representation is a reasonable approximation to Canada's interwar international economic status. While the interwar gold exchange standard, which effectively fixed bilateral currency exchange values by specifying gold par values for each individually, broke down following Britain's abandonment of the regime in 1931, the arguments posed by Bordo and Redish (1990) and casual observation suggest that Canada pursued a fixed exchange rate policy against the U.S. dollar for most of the sample period studied here. Equally, although Canada's capital markets were underdeveloped relative to those in many Western nations during the interwar era they were well integrated with equivalent U.S. and British markets. Inspection of interwar time-series for nominal interest rates of similar maturity and risk characteristics in Canada and the U.S. also suggests that the capital market integration assumption is tenable.[3]

Specifically, I present a stochastic small open economy model in the Mundell-Fleming tradition. The domestic open economy is represented by an IS-LM construct augmented with an output supply function that permits permanent output growth due to stochastic changes in the quantity of resources, the supply of labour and capital, and technology. Domestic output is exogenously determined in the long-run by this aggregate supply component; the 'stochastic output trend'. However, the model admits short-run deviations from trend following unpredictable domestic and external disturbances to aggregate expenditure with nominal rigidities represented by an expectations augmented Phillips' Curve.[4]

This Mundell-Fleming framework accomodates short-run domestic output fluctuations in response to both real and nominal foreign disturbances and to local shocks. This contrasts with classical small open economy representations in which foreign shocks are absorbed by domestic money and price level fluctuations, with output fixed at its supply determined level. The framework is consistent with previous analyses of the interwar years in Canada which discuss how 'world' and, especially, U.S. real and nominal shocks caused Canadian output fluctuations.[5] Since the Mundell-Fleming analytic framework yields testable implications for the transmission of foreign disturbances, dynamics and equilibrium for a small open economy, I can evaluate directly its validity in the interwar data by estimating an empirical system that is identifiable with models of this class.

2.2.2 The Model

Assume that 'Canada' is a small, open, monetary economy in a multiple currency world and accounts for a negligible fraction of total world output, trade, capital and money. The international

[3]While the magnitude and nature of domestic fluctuations induced by external disturbances is conditional on the degree of capital market integration, for the purposes of exposition I present a model reflecting the most extreme case.

[4]The model therefore accomodates the well-documented fact that output can be represented as a stochastic non-stationary (unit root or integrated) process. This property implies, as described in Quah (1992), that some of the multiple fundamental stochastic determinants of, or economic disturbances to, output have effects which never die out. I follow standard macroeconometric interpretation of the permanent component of output as being 'long-run aggregate supply' with residual, purely transitory variation taken to be the result of 'demand' shocks. The origin of this idea and its defence can be found in Blanchard and Quah (1989). Subsequent empirical applications include Cecchetti and Karras (1992), Gali (1992) and Ahmed et al (1993).

[5]Safarian's informal (1959) Mundell-Fleming open economy analysis and Green and Sparks's (1988,1992) IS-LM-BP framework are leading examples in the Canadian literature, while many of the models used by Temin (1989) and Eichengreen (1990) in discussing international aspects of the Depression more generally involve similar structures. McCallum (1989) presents a thorough analysis of the properties of traditional classical and Mundell-Fleming models and of static small open economy equivalents.

monetary regime is exogenous and fixes the exchange rate of the domestic currency against the (average) currency in the rest of the world. A simple linearized representation for such an economy is

$$y_t = \theta_t - a_1(p_t - p_t^* - e) - a_2(R_t - E\Delta p_{t+1}) + \eta_t^d \quad (1)$$

$$p_t = E_{t-1}p_t + b_1(y_t - \theta_t) \quad (2)$$

$$\theta_t = \theta_{t-1} + \eta_t^s \quad (3)$$

$$(m_t - p_t) = c_1 y_t - c_2 R_t + \eta_t^{md} \quad (4)$$

$$R_t = R_t^* \quad (5)$$

where all variables are expressed in log-levels and as deviations from mean, except nominal interest rates which are specified as deviations from mean in levels. All coefficients and elasticities in the model are measured as absolute values. The η_t^i 's represent the fundamental disturbances of the model which generate stochastic fluctuations in the macroeconomy. Each element of the η_t vector is a white noise stochastic process, (it has zero mean, is serially uncorrelated and has constant finite variance), which is orthogonal to the other disturbances in the model contemporaneously and at all leads and lags.

(1) is an expenditure function. Expenditure on Canadian output in the public and private sectors comprises consumption, investment and net exports which depend negatively on the terms of trade with the rest of the world and the expected real interest rate and positively on an autonomous aggregate demand disturbance. This disturbance can represent fiscal policy and preference shocks, for example. Expenditure also depends on the term θ_t which, in equation (2), represents the long-run level of output to which the economy returns in the absence of disturbances (price surprises). I view this as fundamentally supply determined by the quantity of resources in the economy and by technology. The generating process for θ_t is given in equation (3), where η_t^s is the underlying white noise supply shock. This unit root specification implies that any supply shock has a permanent effect on the level of output and admits the standard macroeconometric interpretation of the permanent stochastic component of output.[6] Long-run equilibrium is characterized by equalization of aggregate expenditure to *long-run* aggregate supply so that output is determined only by the cumulative effects of past supply shock realizations or its 'permanent' component. Supply shocks directly impact expenditure through the effect of technology shocks on investment demand and, in aggregate data, any change in the level of demand due to permanent labour supply shifts.

[6] To illustrate, if $x_t = x_{t-1} + u_t$, where u can be any stationary invertible autoregressive moving average process, then x can be rewritten as $x_{t-1} = x_0 + \sum_{i=0}^{t-1} u_{t-i}$; every realization of the stochastic error driving u has a permanent, equal effect on the level of x.

Equation (4) represents money market equilibrium. The demand for real balances is determined by domestic income, the nominal interest rate and a fundamental money demand disturbance. Finally, equation (5) presents the condition for capital market integration under the assumption that the nominal exchange rate between Canada and the 'rest of the world' is fixed and where Canada is small. Specifically, instantaneous uncovered interest rate parity holds.

No independent policy rule or generating process is specified for the money stock which is determined endogenously for a small open economy on a fixed exchange rate with perfect capital mobility. Output and prices are determined in goods markets (equations (1) and (2)), taking as given external prices and interest rates. Given output and prices, domestic asset demand disturbances and the world interest rate, the domestic money supply must respond with complete elasticity to equilibrate asset markets following both external and domestic disturbances. The small open economy system is 'recursive' even in the short-run. In particular, any nominal or real external disturbance that affects prices or interest rates in the rest of the world can invoke transitory fluctuations in the domestic price level and output and, therefore, in the money supply.

To close the system requires a specification for the 'rest of the world'. I assume that the coefficients and elasticities in the Canadian model economy are approximately equal to those in the rest of the world. I also assume that the underlying fundamental stochastic processes satisfy the same properties worldwide.

$$y_t^* = \theta_t^* - a_2(R_t^* - E\Delta p_{t+1}^*) + \eta_t^{d^*} \tag{6}$$

$$p_t^* = E_{t-1}p_t^* + b_1(y_t^* - \theta_t^*) \tag{7}$$

$$\theta_t^* = \theta_{t-1}^* + \eta_t^{s^*} \tag{8}$$

$$(m_t^* - p_t^*) = c_1 y_t^* - c_2 R_t^* + \eta_t^{md^*} \tag{9}$$

$$m_t^* = \bar{m}_t^* + \gamma\theta_t^* \tag{10}$$

$$\bar{m}_t^* = \bar{m}_{t-1}^* + \eta_t^{ms^*} \tag{11}$$

The interpretations of equations (6)-(9) are the same as for the Canadian economy, although there is by definition no role for 'external' determinants, and equations (10) and (11) specify the exogenous stochastic process for the money stock in the rest of the world.

Equation (10) states that the money stock grows endogenously with permanent output growth and also has an exogenous permanent component which evolves according to equation (11). Under a commodity exchange standard which does not impose 100% reserve backing, the world money stock is roughly proportional to total reserves and monetary policy institutions have some autonomy in determining the level of domestic reserves. I therefore allow for a non-zero monetary policy shock in the rest of the world to reflect the aggregate effects of this leverage, $\eta_t^{ms^*}$, which permanently affects the level of the world money stock. This rationalizes a permanent *nominal* component in the world economy. However, total world reserves of gold and foreign exchange also are driven exogenously by variables such as world income and the level of world trade.[7] I assume, therefore, that the money stock in the rest of the world is determined also by permanent output growth, θ_t^*.

The general, short-run solution for the rest of the world's economy has y_t^*, p_t^* and R_t^* as linear functions of past and current realizations of the four fundamental disturbances $\eta_t^{d^*}, \eta_t^{s^*}, \eta_t^{md^*}$ and $\eta_t^{ms^*}$, while the money stock, m_t^*, is determined only by the permanent money supply and output shocks. Specifically,

$$m_t^* = \lambda_m^*(\theta_{t-1}^*, \bar{m}_{t-1}^*, \eta_t^{s^*}, \eta_t^{ms^*}) \quad (12a)$$
$$p_t^* = \lambda_p^*(\theta_{t-1}^*, \bar{m}_{t-1}^*, \eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}) \quad (12b)$$
$$y_t^* = \lambda_y^*(\theta_{t-1}^*, \eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}) \quad (12c)$$
$$R_t^* = \lambda_R^*(\eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}) \quad (12d)$$

where the λ^*'s are vectors of coefficients in the underlying structural parameters. These solutions imply that Canadian output, prices, and money are determined in the short run by the four external disturbances through the terms of trade and world interest rate in addition to all domestic disturbances. By assumption there is no feedback from Canada to the rest of the world. The solutions are,

$$m_t = \lambda_m(\theta_{t-1}^*, \bar{m}_{t-1}^*, \eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}, \theta_{t-1}, \eta_t^s, \eta_t^d, \eta_t^{md}) \quad (13a)$$
$$p_t = \lambda_p(\theta_{t-1}^*, \bar{m}_{t-1}^*, \eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}, \eta_t^s, \eta_t^d) \quad (13b)$$
$$y_t = \lambda_y(\theta_{t-1}, \eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}, \eta_t^s, \eta_t^d) \quad (13c)$$
$$R_t = \lambda_R^*(\eta_t^{s^*}, \eta_t^{ms^*}, \eta_t^{d^*}, \eta_t^{md^*}) \quad (13d)$$

The current value of each variable in the model except the common nominal interest rate depends on both a permanent, stochastic trend component driven by the non-stationary processes θ and $\bar{m}$ and a second, transitory component due to current realizations of each white noise disturbance.

The *long-run* equilibrium of the model is defined by the absence of new disturbances or price surprises, so that output lies at its exogenous supply-driven level in both the rest of the world and the domestic economy, and transitory dynamics of external and domestic origin disappear. Only permanent components matter. This implies that nominal and real interest rates, and expected and actual inflation rates, are constant at their zero-mean levels in the rest of the world and domestic

[7] McClosky and Zecher (1976) and Eichengreen (1990) Chapter 10 argue this point.

economy. Long-run outputs are given (from (1),(2),(6) and (7)) by

$$y^* = \theta^* \tag{14}$$

$$y = \theta \tag{15}$$

where the long-run levels of θ and θ^* are represented by their conditional expected values. Long-run money market equilibrium in the rest of the world, (9), and domestic goods market equilibrium for the small open economy, (1) and (2), imply that long-run price levels are given by

$$p^* = \bar{m}^* + (\gamma - c_1)\theta^* \tag{16}$$

$$p = p^* + e \tag{17}$$

The long-run price level in the rest of the world, p^*, is determined by the exogenous permanent components of aggregate output and the money stock and, from (1), a long-run purchasing power parity (PPP) relation pins down Canadian prices at this level. Long-run PPP is (implicitly) rationalized by international goods market integration in a single, composite commodity world. Despite the presence of country-specific supply shocks, Canada is too small to affect the common currency world price of the composite commodity. External determination of long-run prices for Canada also determines the associated long-run domestic money stock. Since

$$m = (p^* + e) + c_1\theta \tag{18}$$

and

$$m^* = \bar{m}^* + \gamma\theta^* \tag{19}$$

then, from (16), (18) and (19),

$$m = m^* + e + c_1(\theta - \theta^*) \tag{20}$$

$$m = \bar{m}^* + e + (\gamma - c_1)\theta^* + c_1\theta \tag{21}$$

In the long-run, Canadian monetary authorities accomodate both the exogenously given aggregate supply at home and exogenously fixed world prices for that output by elastically supplying the amount of currency required to ensure that all output is consumed and invested.

2.2.3 Testable Implications Of The Model

These solutions provide some testable implications for international transmission and macroeconomic dynamics. While for simplicity of exposition the model presented has very simple dynamics and is subject to the strong restriction of white noise fundamental shocks, in the empirical work disturbances are represented by *any* invertible, stationary and causal autoregressive moving average (ARMA) process in white noise. In this case, the elements of λ^* and λ associated with the disturbances are lag polynomial, rather than coefficient, vectors.

Three implications for the small economy's dynamics hold in either case, with generalizations in parentheses. First, domestic money stock fluctuations reflect contemporaneous (and historical) realizations of all disturbances in both the domestic and external economies and prevent the transmission of contemporaneous domestic asset market shocks to output. Second, domestic price fluctuations in Canada reflect contemporaneous (and historical) realizations of domestic goods market disturbances and both nominal and real external disturbances which engender transitory deviations from trend in output. Third, domestic output fluctuations reflect contemporaneous (and historical) realizations of all disturbances in the rest of the world and all domestic shocks except those originating in domestic asset markets.

Additionally, the model predicts that the impact and short-run responses of all variables in the model will differ across the two economies due to international transmission even though long-run responses may be identical. Since the domestic economy is subject to shocks of both domestic and external origin in the short-run, the vectors of (lag polynomial) parameters λ and λ^* will in general differ across the two economies. Moreover, the rest of the world's economy is not affected by Canadian disturbances and the money stock in the rest of the world is unaffected by any but the autonomous nominal and real permanent external shocks.

The solutions also generate testable implications for long-run equilibrium. The theoretical model rationalizes stochastic non-stationarity in the log level of output, prices and money both in the domestic and world economies, so these implications take the form of conditions on common stochastic trends or cointegrating relations between variables both within and across countries.[8] When variables share common stochastic trends, common sources of non-stationarity cancel out in the unique linear combination which represents a structural equilibrium relation. Consequently, although money stocks, prices and outputs are individually non-stationary, and so can wander widely with no mean reverting tendancy, their equilibrium linear combinations *are* stationary and the variables trend together over time. The current representation in ARMA disturbances implies that we should observe purely transitory stationary deviations from three, long-run equilibrium conditions.

First, there is a long-run money market equilibrium condition in the external economy which

[8] See Engle and Granger (1987) for definition and discussion of cointegration in time-series.

implies that prices in the rest of the world inherit the stochastic trends in output and the nominal money stock (see (16)). Second, long-run purchasing power parity holds, that is, Canadian prices share this stochastic trend of prices in the rest of the world (as in (17)). Third, there is a long-run money market equilibrium condition for the domestic economy in which the nominal money stock inherits the stochastic trends in money and output in the rest of the world and in domestic output ((20) and (21)). While the first two equilibrium conditions are shared by many closed and two-country models with long-run price flexibility, the third uniquely characterizes international monetary equilibrium for a small open economy of this class.

Additionally, given the similar behaviour of output across countries in the inter-war data, I also test for common supply shocks; for a common stochastic trend in the domestic and external economies' output series. This common trend could be rationalized by world technology shocks or technology shocks which are diffused rapidly across geographic and economic boundaries. Satisfaction of such a common trend characterization of the data would imply that, provided international money market equilibrium (20) holds, domestic nominal money, real money and velocity share stochastic trends with their external counterparts.

2.3 Econometric Methodology

2.3.1 Overview

I estimate a moving average representation (MAR) for integrated macroeconomic data from the interwar era for Canada that accounts for and uses information on common stochastic trends. The Canadian macroeconomic variables of interest are assumed to be jointly determined by a set of fundamental (orthogonal) disturbances with interpretation as internal and external shocks to a small open economy with short-run non-neutralities due to nominal rigidities. The MAR expresses the current value of each variable as the cumulative effect of current and past realizations of this set of disturbances. It can represent the dynamics of the small open economy model maintained as generating the Canadian macroeconomy, subject to the long-run equilibrium constraints of the model which take the form of common stochastic trends. The estimated responses of the empirical model to each type of disturbance can then be inspected and their consistency with the stylized responses predicted by the Mundell-Fleming small open economy framework evaluated.

2.3.2 The Structural Moving Average Representation

Recent advances in macroeconometric theory and practice mean that the methods required to conduct this empirical analysis are well documented and so only a brief review of the methodology is presented here.[9]

Assume that ΔX_t is an N-vector of jointly covariance stationary variables (X_t requires first differencing to achieve stationarity) such as $[\Delta y_t, \Delta y_t^*, \Delta m_t, \Delta(m_t^* + e), \Delta p_t, \Delta(p_t^* + e)]$ where the elements of X_t are cointegrated. I posit the existence of a structural MAR for some appropriate transformation of the elements of X_t in an N-vector of fundamental disturbances, η_t, which have interpretation as the shocks in a simple open economy Mundell-Fleming model when some of the shocks are known to be permanent for and common to the elements of X_t. This representation in η_t is assumed to be 'complete'; given the maintained model, it fully captures the determination, dynamics and interrelations of the N variables.[10] The MAR also is assumed to be fundamental for X_t[11] and to account for common stochastic trends or long-run equilibrium relations between the elements of X_t.

The objective is to study the dynamics and long-run properties of this structural system to shed light on sources of output fluctuations by estimating an empirical representation. We know from Engle and Granger (1987) that in the presence of cointegration in levels between the elements of X_t simple MAR representations for ΔX_t in η_t of the form

$$\Delta X_t = D(L)\eta_t \tag{22}$$

are misspecified since there are fewer independent permanent shocks in the system than is implied by the N-variable specification. One or more of the shocks must be purely transitory for all variables and the long-run multiplier matrix

$$D(1) = \sum_{i=0}^{\infty} D_i \tag{23}$$

which represents the cumulative effect of shocks on the first difference of X or the infinite horizon effect on the level of X is singular, having one or more columns containing all zeros. The correct structural representation for cointegrated X_t restores the long-run multiplier matrix to full rank by renormalizing the system to account for the cointegrating relations. The resulting vector-error correction, or alternative triangular, system contain equivalent information and the triangular form is applied here. [12]

The structural MAR for the triangular representation is given by

[9] See, for example, Blanchard and Quah (1989), and King, Plosser, Stock and Watson (1991).

[10] See Quah (1992). I also assume that conditions required for an N-disturbance representation to approximate an underlying generating process for X of higher dimension are satisfied. Blanchard and Quah (1989) present a discussion, Theorem and proof.

[11] Lippi and Reichlin (1993) and Blanchard and Quah (1993) discuss conditions under which an assumption of fundamentalness of the MAR may not be valid.

[12] Phillips (1991) discusses the properties of triangular systems.

$$\begin{bmatrix} \Delta X_{1_t} \\ (X_{2_t} - \alpha X_{1_t}) \end{bmatrix} = \Gamma(L)\eta_t \tag{24}$$

where X_t is partitioned into subvectors X_{1_t} and X_{2_t} of dimension N1 and N2, N1+N2=N, and α is an (N1×N2) matrix of (known) cointegrating coefficients where N2 is the number of cointegrating relations and N1=N-N2. The matrix lag operator, $\Gamma(L)$, can be partitioned conformably with X_t into $\Gamma_1(L)$ and $\Gamma_2(L)$ of dimensions (N1×N) and (N2×N) respectively. The (N×1) error vector η_t represents the set of structural disturbances from the theoretical model with covariance matrix Σ_η diagonal to reflect orthogonality of these disturbances. All dependent variables in this representation are stationary so that estimation of and inference from an associated reduced form is based on standard asymptotic distribution theory.

The structural MAR can be estimated, given knowledge of the cointegrating vectors, as a reduced form VAR

$$B(L)\begin{bmatrix} \Delta X_{1_t} \\ (X_{2_t} - \alpha X_{1_t}) \end{bmatrix} = \begin{bmatrix} \epsilon_{1_t} \\ \epsilon_{2_t} \end{bmatrix} \tag{25}$$

with X_{1_t} and X_{2_t} defined as above. B(L) and ϵ_t are the reduced form parameter and error vectors respectively and can be partitioned conformably with X_t. The reduced form has impact matrix B(0) = I and variance-covariance matrix $E(\epsilon_t \epsilon_t\prime) = \Sigma_\epsilon$. Inversion yields the infinite order reduced form MAR

$$\begin{bmatrix} \Delta X_{1_t} \\ (X_{2_t} - \alpha X_{1_t}) \end{bmatrix} = C(L)\begin{bmatrix} \epsilon_{1_t} \\ \epsilon_{2_t} \end{bmatrix} \tag{26}$$

where $C_i(L) = [B_i(L)]^{-1}$ and $C(0) = [B(0)]^{-1} = I$. From this reduced form the underlying structural MAR can be identified given standard algebraic relations between the reduced form and structural parameters and identifying restrictions imposed by theory.

By assumption, $C(L)\epsilon_t = \Gamma(L)\eta_t$. This implies that $\Gamma(0)\eta_t = \epsilon_t$ and that the structural MAR polynomial is given by

$$\Gamma(L) = C(L)\Gamma(0) \tag{27}$$

Therefore, both the structural parameters in $\Gamma(L)$ and innovations η_t can be identified from the reduced form estimates if $\Gamma(0)$ is known. In practice, the structural impact multiplier matrix is not known and must be estimated. In the absence of additional information there are fewer known reduced form coefficients than unknown structural parameters. This requires that $\Gamma(0)$ be identified by imposing restrictions on the structural parameters to reduce the number of unknowns.

Some information is available which can be used directly in the identification of $\Gamma(0)$. From above there is a covariance condition to be satisfied which uses reduced form information:

$$\Sigma_\epsilon = \Gamma(0)\Sigma_\eta\Gamma(0)\prime \tag{28}$$

where Σ_η is assumed to be diagonal or, as here, normalized to be the identity matrix. This condition provides (N(N+1)/2) non-linear restrictions on the elements of $\Gamma(0)$. Since there are N^2 unknown elements in $\Gamma(0)$, exact identification calls for another (N(N-1)/2) restrictions.[13]

I follow Blanchard and Quah (1989) by using zero restrictions implied by the Mundell-Fleming model on the matrix of long-run multipliers $\Gamma(1) = \sum_{i=0}^{\infty}\Gamma_i$ as the remaining identifying assumptions. Such restrictions are meaningful only in the presence of non-stationarity. If the vector, X_t, is stationary $\Gamma(1)$ is a zero matrix since no shock can permanently affect the level of stationary variables. Unit roots in the variables of a MAR system, however, can always be decomposed into a transitory and a permanent component (Quah (1992)), each of which can be viewed as having multiple structural sources. In multivariate systems that allow identification of multiple structural disturbances, this decomposition can be exploited and the two components isolated by imposing theory-driven zero restrictions on $\Gamma(1)$. By using all of the zero-parameter long-run restrictions of the Mundell-Fleming model, in addition to three other (short-run) implications as linear restrictions on the elements of $\Gamma(0)$ (see Section 2.5), the structural parameters and disturbances can be just identified.[14] The resulting estimates of $\Gamma(L)$ and η_t describe the propagation mechanisms for growth rates, and $\Gamma(L)/(1-L)$ describes the dynamics and long-run properties for the levels of variables which are of most interest.

2.3.3 Model Specification Tests

I can directly evaluate whether the data are consistent with the model's implications in several ways using this empirical framework. First, I assess which of the model's long-run equilibrium constraints can be imposed on the triangular specification in the form of the 'error-correction' terms with univariate and multivariate integration and cointegration tests. These inform on whether individual variables and their linear combinations are stationary, and on the number of independent stochastic trends in the data. The tests are commonly applied in empirical macroeconomics and

[13]A number of alternative approaches have been employed to derive such restrictions. Sims (1980) identifies $\Gamma(0)$ by assuming that it is lower triangular (a Wold causal chain generates the system which is said to be resursive). Bernanke (1986), Fackler and Parker (1990) and others estimate 'structural models' of the contemporaneous relations; rather than arbitrarily assume recursivity in $\Gamma(0)$ they impose identifying restrictions derived from economic theory. These approaches do not use long-run information implied by theory which implies restrictions on the long-run multiplier matrix, as I do, although such restrictions are often less arbitrary and controversial than those placed on contemporaneous relations.

[14]I follow Cecchetti and Karras (1991), Gali (1992) and Ahmed at al (1993) in extending Blanchard and Quah's (1989) bivariate decomposition of output fluctuations to the multivariate case.

are not discussed further here.[15]

Second, I evaluate consistency of the multivariate triangular reduced form selected by the non-stationarity tests with a decomposition for the non-stationary variables into transitory and permanent components using the Granger-priority test suggested by Quah (1992). This involves applying a standard χ^2 block-exogeneity test to the lags of $X_{2_t} - \alpha X_{1_t}$ in the equations for ΔX_{1_t}. If the block of lags for the error-correction terms have no predictive power for ΔX_{1_t}, while the converse does not hold, the implied MAR with innovations orthogonalized by zero restrictions on $\Gamma(1)$ has no permanent/transitory decomposition for ΔX_{1_t}. Specifically, this structural MAR has zero coefficients at all lags for shocks to the transitory component for the integrated variables and zero restrictions applied to elements of $\Gamma(1)$ to invoke a permanent/transitory decomposition cannot be justified.[16]

Finally, consistency of the data with the model's predictions for short-run dynamics and international transmission of disturbances is evaluated by inspecting the estimated dynamics of the structural MAR. The information admitted by such inspection is conditional on the presence of 'overidentifying restrictions' for the theoretical model. The model in Section 2.2 generates many long-run and some short-run implications which can be imposed as zero and linear restrictions to identify the structural MAR parameters and innovations with those of the economic model. However, there are more of these restrictions than are required to exactly-identify the N^2 elements of $\Gamma(0)$ in the empirical representation. I therefore select a subset of these economic restrictions to identify the structural MAR and can assess the compatibility of the estimated innovations, responses and variance decompositions with the remaining, non-imposed and testable implications of the model.[17]

2.4 Data Analysis

I make the strong assumption that the U.S. data can represent the rest of the world relative to Canada. However, the arguments of Bordo and Redish (1990) that Canada fixed her currency exchange rate against the $U.S. for most of the interwar era, and the large fraction of external trade in goods and assets for Canada accounted for by the U.S., suggest that this is a reasonable first approximation.

I use monthly data, deterministically adjusted for seasonality, on six variables of interest for the interwar subsample 1924:1-1939:12 : Canadian and U.S. industrial production, wholesale prices

[15] See King, Plosser, Stock and Watson for data analysis that is motivated by the same concern with model specification.

[16] See Quah (1992) for details, theorem and proof.

[17] See Gali (1992) for use of overidentifying restriction tests as evaluation of a macreoconomic model.

and M1 money stocks, where the U.S. price and money stock variables are adjusted by the nominal Canada/U.S. exchange rate and all variables are expressed as natural logarithms (unless otherwise stated). The exchange rate adjustment is consistent with the model and does not alter the time-series properties of the data given Canada's fixed exchange rate policy for much of the sample period.[18] Since real and nominal interest rates are predicted to be purely endogenous, stationary outcomes of the model we do not incorporate them explicitly in my empirical representation in the interests of parsimony.[19] The sample period 1925:1-1939:12 is used in all tests and regressions, with values for 1924:1-1924:12 used up as lags in pre-estimation data analysis and in VAR lags and lag length tests. Data sources, notation and definitions are given in Table 2.1. All notation in the text now reflects use of U.S. and Canadian data to represent the rest of the world and the domestic small open economy respectively.

2.4.1 The Interwar Data

Figures 2.1a-2.1f and Tables 2.2a, 2.2b and 2.2c present some informal (unconditional) evidence on the behaviour of important Canadian and U.S. variables during the Great Depression. The figures, which plot the seasonally adjusted data normalized to the 1935-1939 average, show the very similar behaviour of the Canadian and U.S. economies during the interwar period. Although each pair of series display some different short-run movements, they appear to 'trend together' and the dip in outputs, money supplies and prices during the 1929-1933 era is synchronized across the two countries. Exchange rate adjustment of the U.S. data appears not to cause significant deviations from common movements in the data. The similar bivariate trend behaviour of the series suggests the possibility of cointegrating relations between outputs, prices, money stocks and velocities which is consistent with the model in Section 2.2 amended to allow for common stochastic output trends.

Table 2.2a shows positive average monthly output growth for the period 1925:1 to 1928:12 for both economies, and a high growth rate for Canada in particular, with 'business cycle peaks' occuring in the first half of 1929. The Depression sample trough for industrial production in the U.S. occurs before that in Canada (July 1932 and February 1933 respectively). Mean output growth rates are negative for both series during the Depression era (although positive in the other subsamples), mean levels are lowest and variablility highest. Additionally, the sample correlation

[18]Repeating the analysis of this paper using the unadjusted M1 and price series changes few results. Despite the depreciation of the exchange rate due to Britain and the U.S. leaving the Gold Standard in 1931 and 1933, the time-series properties of the data, non-stationarity, cointegration and estimated VAR results are qualititatively unchanged. Few qualitative changes arise in the innovation accounting exercises.

[19]The responses of the remaining six variables to the disturbances that I identify will therefore reflect interest rate behaviour.

of outputs is highest for this mid-sample period suggesting a peculiar strength of *common* factors during the Depression. Output in neither country recovers to its 1929 peak level by the end of 1939, nor does it fall to its 1934, recovery level during the recession of 1937-1938, reflecting the strong persistence of the Depression. Overall, the output data suggest very similar properties and timing of business cycle peaks, troughs and persistence during the interwar era for the U.S. and Canada.

M1 money stocks exhibit very similar patterns of behaviour in log levels and first differences to those of production, although the U.S. series attains its trough only in 1933:11. The timing of collapse and recovery is otherwise similar. Money stocks are strongly contemporaneously correlated, implying that the small open economy, fixed exchange rate implication for external determination of the Canadian money stock may be valid. The behaviour of prices mimics that for outputs and money stocks as expected; again, the two series exhibit strong similarities in their unconditional properties and in the timing of peaks and troughs. The Depression era is characterized by mean annual deflation rates of 6% for both price series, and the full sample estimate of their contemporaneous correlation is remarkably high, 0.97. These statistics illustrate common nominal properties in the two economies which, in the context of the Mundell-Fleming model of Section 2.2, may indicate that gold standard mechanisms functioned efficiently.

While these statistics suggest close links between the two economies during the interwar era and the Depression in particular, more formal analysis which studies conditional correlations in the data is required to identify the nature of these relations. Preceding Sections argue that evaluation of the appropriate time-series representation for each series, and of the presence and number of common stochastic trends in the data in particular, is an important pre-estimation specification test. I therefore apply standard tests for non-stationarity and cointegration which allow inference on whether the theoretical equilibrium constraints outlined in Section 2.2 are satisfied in the data.

2.4.2 Tests For Non-stationarity And Cointegration

Tables 2.3a and 2.3b present evidence that each of the variables can be represented as a unit root process; as containing a stochastic trend. Table 2.3a presents computed values for the Phillips (1987) Z_α and Z_t and the Dickey-Fuller (1976,1979 and 1981) t-statistics which test the null hypothesis of a unit root in the level of each series against the one-sided alternative that the series is stationary. The evidence is consistent with the null for all series examined. Table 2.3b presents evidence *against* the null for the first difference of each series.[20] I therefore treat each series in

[20]The evidence conflicts with findings of non-stationarity in *post-war* inflation rates. Estimates of the autoregressive coefficients for inflation rates in Canada and the U.S. in the ADF(4) test regression are 0.54 and 0.57 respectively. This suggests that inflation rates are stationary. Since there is also no evidence of non-stationarity in M1 or output

the vector $[y_c, m_c, p_c, y_{us}, (m_{us} + e), (p_{us} + e)]$ as a univariate unit root process which requires first differencing to achieve stationarity.

This implies that all series are subject to permanent shocks. In general, one cannot uncover the sources of these permanent shocks using univariate methods. However, cointegration tests inform on the data's consistency with the model's implications for structural long-run equilibrium relations reflected in common sources of stochastic trends in the data. I use the same Phillips and Dickey-Fuller statistics to test the null hypothesis that the residual series from each cointegrating regression is non-stationary or, equivalently, that there is no cointegration between variables in the regression. Table 2.4a presents results of univariate tests of cointegration applied to the residuals from the cointegrating regressions of the dependent variable on the regressor specified.

Consistent with the long-run equilibrium conditions (16) and (18), I cannot reject the null of non-cointegration for money and prices for either country (rows 5 and 6 of Table 2.4a). This implies that prices in the rest of the world absorb permanent components additional to those reflected in the money stock, and that while long-run PPP determines prices in the small open economy, the domestic money stock will also reflect long-run asset market equilibrium conditions. The Phillips' test statistics in the first three rows of Table 2.4a provide strong evidence to favour bivariate cointegrating relations for Canadian and U.S. outputs, prices and money stocks. Weaker support is supplied by the Dickey-Fuller test results for these hypothesized equilibrium relations. Cointegration of outputs implies there is a common stochastic trend in outputs which, under the maintained hypothesis that only aggregate supply shocks matter for production in the long run, reflects common aggregate supply conditions. The common trend in prices reflects, under the maintained model, an unconstrained long-run PPP relation with common trend generated by aggregate supply shocks and money supply shocks in the U.S. economy. Finally, cointegrated nominal money stocks is an implication of the first two results and reflects the international monetary equilibrium condition, (20). The common trend in money stocks is generated by permanent money supply shocks in the U.S. and the common permanent real shock.

There is *no* evidence to support cointegration of domestic real money balances with domestic output for either country; of long-run domestic money market equilibrium of the form (4). Notably, the addition of nominal interest rates to the money market equilibrium relations had no qualitative effect on this result, so the omission of interest rates is not important for this conclusion. Non-cointegration of domestic money demand functions implies that *both* economies are subject to permanent money demand or 'independent velocity' shocks in asset markets.[21] Since nominal

growth rates, this seems an appropriate 'structural' conclusion.

[21] In general, this result will reflect any misspecification of the equilibrium conditions for asset markets. However,

money stocks and prices *do* cointegrate, these permanent velocity shocks must be common to the two economies. If the money demand shocks are non-stationary processes and do not 'disappear' in long-run equilibrium, the long-run U.S. price level is given by $p_{us} = m_{us} - c_1\theta^{us} - \eta^{md^{us}}$ and the long-run Canadian money stock by $m_c = p_{us} + e + c_1\theta^c + \eta_c^{md}$. Given common θ's, $m_c = m_{us} + e + \eta^{md^c} - \eta^{md^{us}}$ and so cointegration of nominal money stocks requires cointegration of the money demand processes; common money demand shocks. Long-run prices in both economies must contain a component due to this permanent asset market shock which provides additional rationalization for the non-cointegration of money and prices in each economy.

In Table 2.4b, I impose some coefficient constraints implied by theory. First, I assume that the common aggregate supply shock has an equal long-run impact on the logarithms of output, or a proportional effect on the levels. Second, I assume that there is a constant, proportional relationship between prices in the U.S. and Canadian economies in the long-run, or impose relative long-run PPP, as predicted by (17), and also impose the (1,-1) coefficient vector in the money stock (and real balance and velocity) cointegrating regression implied by the condition for international monetary equilibrium, (20). These restrictions allow application of simple non-stationarity tests to the log-differences of outputs, prices, and money stocks. Tests for non-stationarity of real balances confirm non-cointegration of money and prices for each country in rows 5 and 6. The results document strong support for the coefficient restrictions at the 5% level for all but the long-run PPP relation, which is favoured at the 10% and 15% levels, as shown in the first three rows of Table 2.4b.

In Table 2.4c, Johansen's maximum-likelihood multivariate cointegration test statistics are applied to confirm inference drawn from the univariate results that there are three, independent common stochastic trends in the data. These multivariate tests use rank conditions to evaluate the dimension of a multivariate system. Specifically, they test the null of no more than r-cointegrating vectors in a given system against the alternative of more than r cointegrating vectors, and provide unnormalized maximum-likelihood estimates of the space of cointegrating vectors. I evaluate the number of independent cointegrating vectors in the six variable system $[y_c, m_c, p_c, y_{us}, (m_{us} + e), (p_{us} + e)]$. Univariate tests imply that there are three such vectors in the system; one in the two output series, which reflects purely the common stochastic supply trend, one in the two money stock series, which additionally reflects the nominal money stock trend, and one in the two price series, which incorporates additional permanent components due to aggregate supply and money demand shocks. The system should therefore be three-dimensional, have 'rank three' or contain three independent unit roots.

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there is sufficient evidence from contemporary and historical data to support cointegration in such simple money demand specifications to warrant the labeling of this result an outcome of permanent velocity shocks.

The first line of Table 2.4c shows that although I firmly reject the null of no cointegration in the system, I cannot reject the null of three independent cointegrating vectors. Tests of hypotheses about intermediate numbers of vectors suggest that there are no fewer than two independent cointegrating relations in the system which is also consistent with a three unit root specification. In addition, the Johansen procedure rejects the null of no cointegration for the bivariate systems in outputs, money stocks and prices at least at the 15% level for all cases but cannot reject the null of no cointegration between money and prices or real balances and output (no long-run money demand equilibrium) for either country's data.

The bivariate systems estimated in the Johansen tests imply normalized cointegrating vectors given in Table 2.4d. These are consistent with theoretical priors in the output, money supply, real balance and velocity equations and there appears to be a long-run PPP relation with a coefficient close to but not equal to unity. Point estimates of the cointegrating vectors are also provided by the Phillips-Hansen Fully Modified procedure which shows some deviation from unit vectors. Subsequent sensitivity analysis showed that imposition of these alternative cointegrating vectors generates no significant differences in the reduced form or structural model results compared to a system in which unit vectors are imposed for all three cointegrating relations. Consequently, I report results only for the model in which all three unit coefficient restrictions are imposed.[22]

2.5 Identification Of The Empirical Model

The preceding data analysis suggests the existence of three independent common stochastic trends in this data set consistent with the following interpretations. First, there is a permanent output shock which is common to the two economies and interpretable as a world aggregate supply process. Second, there is a permanent nominal shock which is common to the two economies and interpretable as a U.S. policy driven money supply process inherited by an endogenous money stock in the small open economy. Third, (and not predicted by the model), there is a permanent shock to real money demand, and so prices, which is common to the two economies and interpretable as a velocity or money demand process. While the money supply shock can be assumed imported from the U.S. through the fixed exchange rate regime, and the aggregate supply shock to either affect both economies simultaneously or to be rapidly diffused across geographic and economic boundaries, interpretation of the commonality in money demand shocks is not unambiguous. It may represent permanent shocks to the demand for North American currency or assets relative to

[22] I also find that real balances and velocities of the two economies cointegrate, in Table 2.4a, which is implied by bivariate cointegration of outputs, money stocks and prices. Further, they cointegrate strongly with unit coefficient restrictions, supporting the coefficient restriction results for the underlying variables, in Table 2.4b. Johansen tests support these univariate results, in Tables 2.4c and 2.4d.

those in Europe.

In addition to the three permanent shocks I can identify three transitory disturbances in the six variable system. The class of Mundell-Fleming small open economy models illustrated in Section 2.2 suggest the transitory component will incorporate a uniquely U.S. transitory demand shock, a uniquely Canadian transitory demand shock and, under less than perfect capital market integration, possibly a uniquely Canadian transitory money supply shock. Since the current interest is primarily in separately identifying international and idiosyncratic shocks, I attempt only to isolate the U.S. and Canadian elements of the transitory component and not to disentangle individual sources of purely transitory disturbances. Consequently, while I can exactly identify six disturbances in the empirical system, structural interpretation can be placed only on five; shocks to the three, common stochastic trends, an aggregate U.S. transitory component and an aggregate Canadian transitory component.

I identify these disturbances with both long and short-run restrictions. Exact identification requires estimation of 36 elements in $\Gamma(0)$. The covariance condition, $\Gamma(0)\Gamma(0)\prime = \Sigma_\epsilon$, provides 21 of these. As noted in Section 2.3, theory often suggests more restrictions for the structural empirical model than are needed for exact identification and, in fact, I select a subset that provides close correspondence with the small open economy interpretations desired of the six disturbances. Other behavioural restrictions implied by the model (and by history) for the impulse responses and identified disturbances are used to evaluate the model's predictions (as overidentifying restrictions).

Given the unit root and cointegration test results, and the shock interpretations implied by Mundell-Fleming model, I specify and estimate the following empirical system which is the analogue to the triangular system of Section 2.3 ;

$$\begin{bmatrix} \Delta y_{c_t} \\ \Delta m_{c_t} \\ \Delta p_{c_t} \\ (y_{c_t} - y_{us_t}) \\ (m_{c_t} - m_{us_t} - e_t) \\ (p_{c_t} - p_{us_t} - e_t) \end{bmatrix} = \Gamma(L) \begin{bmatrix} \eta_t^{s} \\ \eta_t^{ms^{us}} \\ \eta_t^{md} \\ \eta_t^{d^{us}} \\ \eta_t^{d1^c} \\ \eta_t^{d2^c} \end{bmatrix} \tag{29}$$

Subscripts now denote country of origin and date, respectively, and superscripts denote shock type and country of origin respectively. Where shocks are common to the two economies a single superscript appears. This system is identified by applying the following restrictions.

First, in the hypothetical long-run with no new disturbances, the variables are assumed to be generated by the stochastic trend representation:

$$\begin{bmatrix} \Delta y_{c_t} \\ \Delta m_{c_t} \\ \Delta p_{c_t} \\ (y_{c_t} - y_{us_t}) \\ (m_{c_t} - m_{us_t} - e_t) \\ (p_{c_t} - p_{us_t} - e_t) \end{bmatrix} = \begin{bmatrix} \Gamma_{11}(1) & 0 & 0 & 0 & 0 & 0 \\ \Gamma_{21}(1) & \Gamma_{22}(1) & 0 & 0 & 0 & 0 \\ \Gamma_{31}(1) & \Gamma_{32}(1) & \Gamma_{33}(1) & 0 & 0 & 0 \\ \Gamma_{41}(1) & \Gamma_{42}(1) & \Gamma_{43}(1) & \Gamma_{44}(1) & \Gamma_{45}(1) & \Gamma_{46}(1) \\ \Gamma_{51}(1) & \Gamma_{52}(1) & \Gamma_{53}(1) & \Gamma_{54}(1) & \Gamma_{55}(1) & \Gamma_{56}(1) \\ \Gamma_{61}(1) & \Gamma_{62}(1) & \Gamma_{63}(1) & \Gamma_{64}(1) & \Gamma_{65}(1) & \Gamma_{66}(1) \end{bmatrix} \begin{bmatrix} \eta_t^{s} \\ \eta_t^{ms^{us}} \\ \eta_t^{md} \\ \eta_t^{d^{us}} \\ \eta_t^{d1^c} \\ \eta_t^{d2^c} \end{bmatrix} \tag{30}$$

where the last three rows of $\Gamma(1)$ are all zeros by cointegration which imply stationarity of the three log-differenced variables. The long-run zero constraints in the first three rows comprise 12 of 15 restrictions that are imposed on the system. These uniquely identify three permanent disturbances, by assuming that each has a unique influence on the system, using only long-run restrictions in a lower triangular long-run multiplier matrix.[23] These restrictions, in accordance with the interpretations placed on the shocks by the model of Section 2.2, imply that only aggregate supply shocks matter for Canadian and U.S. outputs in the long-run, that only aggregate supply and money supply shocks matter for Canadian and U.S. money stocks in the long-run, and that all three permanent disturbances are absorbed by prices in Canada and the U.S..

In addition, I impose three short-run restrictions to just identify the empirical system. The first two of these identify the aggregate of the last two disturbances as being of uniquely Canadian origin. The third places an additional short-run restriction to identify the money supply shock as an 'exogenous' monetary policy disturbance in the U.S.. These are imposed as linear restrictions on the impact multiplier matrix, $\Gamma(0)$. The first two

$$(\Gamma_{15}(0) + \Gamma_{16}(0)) - (\Gamma_{45}(0) + \Gamma_{46}(0)) = 0 \tag{31}$$

$$(\Gamma_{25}(0) + \Gamma_{26}(0)) - (\Gamma_{55}(0) + \Gamma_{56}(0)) = 0 \tag{32}$$

impose a zero impact effect of the (aggregate) Canadian transitory disturbance for U.S. output and money. There should be no significant feedback from the Canadian to any variable in the U.S. economy of shocks that originate in Canada at any lag, according to my traditional small open economy model. The short-run identifying restrictions impose no *immediate* feedback to output and money. If these uncover the true Canadian component the theoretical restriction should also hold.

The final identifying assumption imposed is that

$$\Gamma_{24}(0) - \Gamma_{54}(0) = 0 \tag{33}$$

This just identifies the system by imposing zero impact effect of domestic real demand disturbances for the domestic money stock in the U.S.. This is the most controversial of the identifying restric-

[23] See, for other lower triangular long-run identifying schemes, King, Plosser, Stock and Watson (1991) and Ahmed et al (1993).

tions, although entirely consistent with the theoretical model. There are other alternative plausible restrictions that could be used to help identify the second permanent disturbance as an exogenous policy shock to the money stock.[24] These are used as overidentifying information (see Section 2.3) to evaluate the model.

This empirical model forces the data to satisfy strong long-run constraints. In particular, the structural specification implies that the Canadian economy is determined by international stochastic trends at the infinite horizon. However, it also admits a significant explanatory role for purely transitory shocks of both Canadian and U.S. origin in generating short-run output fluctuations during the inter-war period. Quah (1992) shows that my multivariate permanent/transitory decomposition of macroeconomic fluctuations has sufficient structure to generate meaningful measures of the relative size of these two components. My short-run restrictions also allow identification of a purely domestic transitory component. I can therefore assess the relative importance both of permanent and transitory *and* of domestic and international disturbances for Canadian output fluctuations during the Great Depression.

2.6 Estimation Results

2.6.1 The Reduced Form Triangular VAR

I estimate the triangular cointegrated VAR. Standard criteria select a four lag specification and a constant term is included in each equation.[25] Some selected statistics are shown in Table 2.5. F-tests of the hypothesis that given blocks of lags in an equation are zero reveal that Canadian money growth responds significantly to all variables in the model, suggesting that the small open economy assumption of money supply elasticity well represents the reduced form behaviour of this variable. Inflation in Canada, moreover, is not significantly predicted by domestic money growth which also implies endogeneity of the domestic money stock. Also notable is the significance of some block of lags of the error-correction terms, $X_{2_t} - \alpha X_{1_t}$ for all of the Canadian growth rate variables.

'Quah' tests applied to the reduced form VAR confirm the F-test results; the computed value of the $\chi^2(36)$ statistic for the null hypothesis that the set of error-correction terms $[(y_c - y_{us}), (m_c - m_{us} - e), (p_c - p_{us} - e)]$ do not help predict $[\Delta y_c, \Delta m_c, \Delta p_c]$ is 103.02 which is significant at less than 1%. Similarly, the integrated part of the system helps predict the error-correction component with

[24]The U.S. money stock should not respond also to money demand disturbances (a zero short-run restriction could be imposed) at any lag, and the money supply shock should have an equal long-run impact on money and prices.

[25]Time trends are insignificant in each equation of the VAR and make no significant difference to the reduced form or structural model results.

a test statistic computed value of 85.32. This system therefore does capture a permanent/transitory decomposition for the integrated Canadian variables.[26]

2.6.2 Computation Of The Structural MAR

I invert the VAR, using 180 reduced form moving average coefficients as the cut off point for the reduced form moving average, and identify the structural MAR as described above using the estimated reduced form coefficients and identifying restrictions.[27] I derive the structural moving average for the *levels* of the Canadian variables by inverting the difference operator in the difference-stationary component, X_{1_t}, of the MAR. I then generate impulse responses for each of the U.S. variables by taking linear combinations of the estimated parameters of the system $[y_c, m_c, p_c, (y_c - y_{us}), (m_c - m_{us} - e), (p_c - p_{us} - e)]$.

I calculate confidence intervals for the point estimates of the structural moving average parameters and structural innovations, and so the impulse responses, forecast error variance decompositions and historical decompositions, using Monte Carlo integration to compute the empirical distributions of these statistics. These one-standard error bands are based on specific distributional assumptions about the parameter estimates of the reduced form.[28] I report bias adjusted estimates when the bias, measured as the difference between the mean of the Monte Carlo draws and the point estimate, is large and significantly alters the results. All standard errors and biases reported are generated from 2500 Monte Carlo draws.

2.6.3 The Identified Innovations

The shocks that I identify, and their one standard error bands, are shown in Figures 2.2a-2.2e. I can infer nothing about the relative importance of each in the Depression without also accounting for the estimated values and significance of the impulse response functions, however, investigating these plots helps evaluate my interpretation of the structural innovations. In particular, I can judge whether remarkable values of the point estimates are consistent with known historical events that can be associated with specific macroeconomic disturbances. In general, the identified disturbances are at least consistent with interpretations implied by the structural model.

[26] This result is invariant to the presence of a time-trend in the VAR equations and to the use of the non-exchange rate adjusted U.S. money supply and price variables.

[27] The solution to $\Gamma(0)$ is derived using a non-linear system solution algorithm available in GAUSS386 (with the default program settings.

[28] Specifically, I assume that the OLS estimate of the VAR variance-covariance matrix, Σ_ϵ, is generated by an inverted-Wishart distribution, and construct a sequence of Σ_ϵ's from which I generate a sequence of the VAR parameter vector in B(L). These two sequences are then used to compute the structural model parameters using the usual identification techniques for each draw in the sequence.

The 1929 recession which precipitated the Depression is preceded by and coincident with several significant events. First, there is a run of significant and negative common supply shocks to output, the η_t^s, from 1929:7 onwards culminating in a large negative supply shock in November of 1929, the month following the Stock Market Crash. These are consistent with Fisher's (1933) hypothesis that negative actual and expected productivity shocks drove the U.S. economy to financial market disaster and into Depression. Second, there is a run of significant, negative autonomous money supply shocks, the $\eta_t^{ms^{us}}$, in late 1928 and early 1929 with a large negative realization in December 1929 which may represent the monetary base contraction initiated by the Federal Reserve stressed by Hamilton (1987) and Friedman and Schwartz (1963). Third, there is a significant negative run of 'velocity' shocks, the η_t^{md}, during late 1928 which represent positive money demand disturbances and could reflect the rising demand for transactions balances in U.S. stock markets.[29] Finally, I identify a series of negative U.S. transitory demand shocks, the $\eta_t^{d^{us}}$, during 1929, which can be associated with Temin's (1976) autonomous demand shocks. The Canadian transitory component, captured by the aggregate $\eta^{d1^c}+\eta^{d2^c}$, is too imprecisely estimated for us to draw inference about its behaviour during 1928 and 1929.

The persistence of the Depression from 1930 to early 1933 is associated with a series of significant, negative aggregate supply shocks over that period, with some large negative autonomous money shocks in early 1930 and in early and late 1932, and with large positive velocity shocks of late 1931 and early 1933. The supply shocks are consistent with Bernanke's hypothesis about the supply effects of financial crises during this period. Similarly, the money shocks in 1930 are consistent with Hamilton's (1987) and Friedman and Schwartz's (1963) assertions that the Federal Reserve pursued contractionary policy during this period. I interpret the velocity shocks as speculative runs against the U.S. dollar during periods of withdrawal from the Gold Standard of key participants.

I also note the identification of significant positive supply, money supply and velocity shocks in September 1939 with the onset of World War II. These are consistent with priors about North American output, monetary policy and money demand responses to the announcement of the outbreak of war in Europe.

[29]While this is a permanent money demand disturbance I identify it only with the long-run restriction that it can permanently affect prices but not the money stock or output. Consequently, it has a long-run positive price effect and behaves like a 'negative' money demand disturbance ; the structural covariance Choleski decomposition is unique up to sign changes.

2.6.4 Impulse Response Functions

Figures 2.3-2.8 show the response of each variable to a one standard deviation innovation to aggregate supply, money supply, and velocity, and to one standard deviation transitory shocks in the U.S. and Canada respectively. One-standard error bands are also plotted.

The response of Canadian output to the supply shock is somewhat unstable during the first few months following the innovation in contrast to the smooth response of U.S. output which rises steadily to its new permanent level. This may be attributable to different dynamic responses of Canadian and U.S. output and prices to the common shock and the consequent impact for export demand and the terms of trade. The overall response for both variables is as anticipated; large, positive, significant and increasing over a one-year period. The initially negative response of production to the money supply shock disappears rapidly.[30] Production in both countries subsequently rises within four months of the money supply shock. However, the responses are insignificant at all lags for both countries except for the very small, significant response at the very first lag for the U.S. economy. A positive velocity shock has a very small, barely significant negative effect for Canadian output at the first lag but otherwise has no significant effect on either output series at any lag. Despite large point estimates, the output responses to the transitory shocks are insignificant.

These results suggest that the data exhibit some, but not all of the dynamic implications of my structural model. For outputs, there are two (sets of) overidentifying restrictions. The first is that there should be no significant response at *any* lag of U.S. output to the uniquely Canadian shock, and this is (essentially) satisfied. Second, the model predicts that impact, and short-run dynamic, responses should significantly differ for all shocks in the two economies. This is also satisfied for the three permanent shocks in the model but not for the transitory shocks, for which short-run responses are zero.[31]

The effect of all shocks on the Canadian money stock is quite unstable at short lags which contrasts with the U.S. responses (Figures 2.5 and 2.6). The supply shock has a small, significant and positive permanent effect on both money stocks. The money supply shock has an immediate, significant positive effect on the money stocks, the permanent effects of which are almost fully realized within six months. The U.S. money stock responds insignificantly to all other shocks at all horizons. There is a very small, barely significant negative response of the money stock in Canada to the velocity shock and a positive response to the U.S. transitory shock.

[30] This negative output response is rationalized by transitory expected inflation effects dominating liquidity effects in nominal interest rates in some models with temporary monetary non-neutralities.

[31] The overidentifying restriction that Canadian output does not respond to domestic asset market shocks is eliminated by the finding of permanent, common money demand disturbances which affect Canadian output through relative price movements.

The structural model's testable predictions for money stock behaviour are largely satisfied in the data. The U.S. money stock responds insignificantly to all but the domestic money supply and common real supply shocks at *all* lags, suggesting that I have successfully identified a policy driven, exogenous money supply shock. In particular, its impact response to the velocity shock is zero though unrestricted. This satisfies one set of overidentifying restrictions for U.S. money stock behaviour. Moreover, the estimated impact responses for the Canadian and U.S. money stocks *do* significantly differ in at least three cases, implying satisfaction of a second subset of testable restrictions that impact (and short-run) responses should differ across the two economies. The Canadian money stock exhibits significant short-run responses to two of the three disturbances which do *not* affect the U.S. money stock at any lag. Furthermore, the signs of the money stock impact responses are consistent with those indicated by the model. These results imply that the predicted short-run adjustment of the Canadian money stock to all disturbances holds in the data at least for external and asset market disturbances. The model successfully replicates this implication of the small open economy model.

The price responses are illustrated in Figures 2.7a-2.7e and 2.8a-2.8e for Canada and the U.S. respectively. Prices in both economies respond positively and significantly to aggregate supply shocks at all but the first lag, and positively and significantly to the autonomous money supply and velocity shocks at all lags, but not to the transitory disturbances. The positive impact of the supply shock on the price levels is, perhaps, counterintuitive but consistent with the Mundell-Fleming model presented in which the sign of the long-run price response to permanent output shocks depends on the relative size of money supply and money demand responses to the disturbance. The price responses to money supply shocks have the expected sign and significance. The positive impact effect of the 'velocity' shock on price levels identifies this as a negative money demand shock; the long-run effect is significant and positive, driving the wedge between money and prices identified in the data analysis. Prices in neither economy respond significantly to the two transitory demand disturbances.

Recall that both the model and the data imply a positive, significant long-run money stock response to the supply shock, which should induce an *equal* long-run price effect. Here, while estimated short-run price effects are barely significant, the long-run price impact is positive and insignificantly different from the long-run money stock response. Moreover, accounting for confidence intervals, the long-run neutrality restriction (16) for autonomous money shocks holds. Consequently, price responses satisfy the overidentifying restrictions that shocks to money stocks have equal long-run effects for prices and, further, this neutrality result is attained well within a twelve month period.[32] U.S. prices satisfy the overidentifying restriction that there is no significant reponse of any U.S. variable to the transitory Canadian shock at any lag, with the exception of a small, significant response at lag 3.

Overall, the data fail to indicate significant short-run non-neutralities of outputs in response to each shock. The largest significant output movements derive from aggregate supply shocks implying a more classical representation than anticipated. In fact, many of these estimated impulses imply real effects for outputs, the output ratio, the terms of trade and real money balances which are quantitively limited and short-lived.

The economic model implies that one of the most important sources of transitory deviations from trend in domestic output is shifts in the terms of trade. The economic history of the global Depression has recently posed terms of trade movements as a primary mechanism for transmission of disturbances from the U.S. economy under the Gold Standard. Figure 2.9 plots impulse response functions and standard error bands for the terms of trade to each disturbance and shows that only permanent velocity disturbances generate significant short-run deviations of the terms of trade from its (zero-mean) equilibrium value. This reflects both the failure of prices to respond signficantly to the two transitory shocks *and* remarkable symmetry in the price responses across the two economies at all leads and lags to permanent U.S. and common shocks. The impulses imply insignificance of this mechanism for transmission of all but common velocity shocks, and such rapidity and completeness of price transmission for permanent monetary and real shocks across national boundaries that there is little support in this empirical representation for the idea the Gold Standard promoted real transmission of these shocks.

2.6.5 Forecast Error Variance Decompositions

The relative effects of standardized shocks on the endogenous variables can be gauged from the forecast error variance decompositions which present the percentage of the total forecast error variance at each horizon attributable to each shock for a given variable. Again, some of the model's testable implications are unconstrained in identification and allow evaluation of the data's consistency with the model.

Table 2.6a shows that a high proportion of the variance in Canadian output can be accounted for by the two country-specific transitory shocks at short horizons, and by the supply shock. As the

[32] Notably, the price response to supply shocks implies that the long-run money demand response, c_1, to permanent output shocks is insignificantly different from zero. This suggests that the standard money demand function does not capture well properties of interwar data.

horizon increases, a rising fraction of the variance is attributable to supply, although the standard errors are large and the point estimates may overstate the rapidity of this rise. The money supply and velocity shocks play no significant role at any forecast horizon. The results are somewhat different in the U.S. case, where the two transitory shocks do not account for a significant fraction of the forecast error variance at any horizon, but the money supply shock accounts for a significant percentage at the one month horizon. These decompositions reassure that the model's implications for exogeneity of the U.S. economy are satisfied. There is no feedback from the Canadian shock to the U.S. economy by this measure but there is a significant role for U.S. originating (transitory) shocks in Canadian output fluctuations. Additionally, by this criterion the two economies exhibit significant differences in output dynamics in response to all shocks.

The money stocks in the two countries also behave quite differently at short horizons, as shown in Tables 2.6c and 2.6d. The supply shock accounts for almost none of the Canadian money stock variance at short horizons, but a significant fraction of the U.S. money stock variance at all horizons. Its importance for Canadian money grows gradually over time, while its importance for the U.S. money stock is unambiguous at all horizons, despite large standard errors for both money stock decompositions. The standard errors do not hide the importance of autonomous money supply shocks at all horizons for both the U.S. and Canadian money stocks. Until the six month horizon a significant percentage of forecast error variance for the Canadian money stock derives from transitory Canadian shocks, suggesting that some Canadian monetary disturbances may have been captured in this component. All of the short-run forecast error variance of the U.S. money stock derives from the money supply and aggregate supply shocks.

The data therefore satisfy the short-run implication of the model that money stock behaviour differs across the two economies. They are consistent with the view that Canada is a small open economy in which the money stock adjusts endogenously to both domestic and foreign disturbances. The U.S. money stock responds only to domestic monetary policy shocks and 'endogenously' to permanent domestic output shocks. This latter characteristic of the U.S. money stock is not strongly reflected in Canadian money stock behaviour for several months suggesting there is short-run divergence between the variance of Canadian M1 and its long-run external determinants.

Tables 2.6e and 2.6f present the forecast error variance decompositions for Canadian and U.S. prices. At long forecast horizons the variance of prices in both countries is explained primarily by the velocity and money supply shocks respectively, with little signficant role for the supply shock. At short horizons the Canadian price level is also significantly influenced by the domestic transitory shock, although there is no significant role for the transitory U.S. shock, while the U.S. price forecast error variance is dominated by velocity shocks. The money supply shock plays a surprisingly small role for both variables at short horizons, however its share in price forecast error variance grows steadily as the forecast horizon is extended. In general, the price decomposition results reflect the same failure of prices to respond significantly to demand components as the impulse responses do.

Overall, these results confirm that the identifying assumptions applied have isolated a uniquely Canadian component which does not significantly impinge on fluctuations in the U.S. economy, and that the monetary implications of the small open economy model of Section 2.2 are satisfied. There is no significant component of any of the U.S. variables' forecast error variance attributable to the Canadian transitory shock at any forecast horizon although the forecast error variance of the Canadian output *is* significantly accounted for by both the Canadian and U.S. transitory disturbances. This suggests that while it has comparatively small importance for U.S. fluctuations, the U.S. disturbance can significantly affect the smaller, Canadian economy through export demand.

2.6.6 Historical Decompositions

The preceding data analysis, estimated innovations, impulse responses and forecast error variance decompositions all reflect an empirical representation for the interwar data from Canada and the U.S. that reasonably captures the dynamics and long-run properties of a small open economy and a large external economy implied by standard Mundell-Fleming open economy models. The least satisfactory assumptions of the structural model for this data are that there will be significant non-neutralities for outputs in both economies from a wide variety of real and nominal disturbances and that terms of trade movements are a primary source of short-term transmitted output shocks for the small open economy. However, most importantly, the estimated innovations and responses appear to reflect quite well standard interpretations of the shocks identified. I therefore turn to evidence provided by the historical decompositions on the 'causes' of the Great Depression in Canada (and the U.S.) using these interpretations.

The historical decompositions shown in Figures 2.10-2.15 combine the information in the impulse response functions with the realized values of the shocks at each point in time. In particular, I depict the 12-month ahead total forecast error for the level of each variable, the forecast error due to each shock and the computed standard errors of the individual forecast error series.

In both Canada and the U.S. the total forecast error for industrial production is negative from early 1930 to early 1933, and again throughout 1938. In addition, the total forecast error for U.S. industrial production is negative in late 1927 and early 1928. In each of these cases, virtually all of the forecast error can be explained by the permanent output (supply) shock (Figures 2.11a and

2.12a). With few exceptions, the other identified shocks have a relatively small and insignificant role in generating unpredictable output fluctuations. The transitory Canadian shocks appear to predict short-run domestic output dynamics well, but have no significant influence for the output collapse or recovery. However, in 1938 positive realizations of Canadian transitory shocks offset permanent output shocks, making the downturn of 1937/8 less severe in Canada than in the U.S.

Figures 2.16 and 2.17 show the decomposition results for output most starkly. These permanent/transitory decompositions plot the permanent and total transitory components of output at each date which are generated by the cumulative effects of aggregate supply shocks and the sum of money supply, velocity, and idiosyncratic shocks respectively. The time path of the total stochastic component of output is almost completely governed by the cumulative effects of aggregate supply disturbances for both countries for the sample period 1929:1-1936:12. Although transitory shocks can account for short-run fluctuations in Canada in the early part of the sample, and money supply shocks generate some pre-Depression fluctuations in the U.S., only permanent output shocks matter for output in both countries from the beginning of 1929.

The fall in output appears to be virtually monocausal, but the behaviour of money and prices is more complex. The total forecast error for money stocks in both countries is comparatively small, but is significantly negative in early 1929 and from early 1930 to early 1934 and especially large in late 1930 and late 1932. The U.S. forecast errors are entirely attributable to a combination of the permanent output and money supply shocks, while in Canada the effect of the transitory Canadian shock (which is an amalgam of both monetary and real idiosyncratic transitory shocks) is correlated with the total forecast error, although rarely significant. The unanticipated decline in money stocks reflects in part an endogenous response to the aggregate supply shocks that caused the output collapse, and in part an exogenous monetary contraction especially in the unanticipated monetary 'trough' of 1930-1931. However, as argued above, autonomous money shock effects had no feed back into output fluctuations.

In Canada there were bouts of unanticipated deflation in early 1930 to mid-1932 and again in early 1933. On each occasion, unanticipated deflation began a few months earlier in the U.S. and, in addition, the U.S. experienced unanticipated deflation in 1938 which does not reflect in Canada. In the U.S., the monetary velocity and aggregate supply shocks contributed in roughly equal measure to the deflation of the early 30s while the hiatus from late 1931 to the end of 1932 reflected the effects of the positive velocity shock of late 1931. The story is similar for Canada with a greater, but insignificant, role for Canadian shocks.

2.6.7 A Note On Robustness

The empirical results proved robust to several changes in specification; most notably, inclusion of the non-exchange rate adjusted U.S. money supply and price series, of the estimated (Phillips-Hansen) error-correction terms rather than the unit valued error-correction vectors, and to the use of different price, output and money stock series for the U.S.. While small quantitative and qualitative changes do arise in the structural estimation results, the main result does not change; common, permanent shocks to output explain the onset, depth and duration of the Great Depression in Canada and the U.S..[33]

2.7 Conclusions

An extensive U.S. literature assumes that the global Depression of the 1930's reflected international transmission of the U.S. output collapse, initiated perhaps by Federal Reserve policy. To test this hypothesis I have estimated a small open economy model for Canada in which the U.S. represents the rest of the world. I exploit common stochastic trends in the U.S. and Canadian macroeconomies to identify international and domestically originating disturbances with standard macroeconomic interpretations and assess their relative contributions to interwar output fluctuations in both economies. I find that the onset, depth and duration of output collapse in both Canada and the U.S. are attributable to a common, permanent output shock leaving no significant role for idiosyncratic disturbances originating in either economy. I conclude by contrasting these results with the hypotheses and empirical results reviewed in Section 2.1.

I do identify the U.S. monetary contraction in late 1928 that Hamilton (1987) emphasized, and the attendant rise in transactions money demand, but these shocks are absorbed by prices and have an insignificant effect on output in both the U.S. and Canada. Similarly, while I find evidence of deflationary monetary policy in 1930 and a significant monetary contraction in 1931 and 1932 to which Friedman and Schwartz (1963) attribute the severity and persistence of the Depression, the former has no significant output effects and the latter I find to be primarily an endogenous monetary contraction as Temin (1976) argued. Idiosyncratic U.S. demand shocks are significant during 1929, as Temin and Romer (1990) asserted, but equally have no output effects in either economy. Consequently, my results reject explanations of the global Depression which emphasize international transmission of autonomous monetary and real disturbances originating in the U.S.

My results also are not supportive of the more general hypothesis that Canada imported the Depression through the collapse of export demand or of export prices. The symmetry of output

[33] Results available from the author upon request.

behaviour in Canada and the U.S. and the insignificance of terms of trade movements in response to all but common asset market disturbances suggest that the Depression in Canada derived from the same sources as that in the U.S. economy rather than being transmitted through export demand. These same symmetry results challenge the views of Temin (1991) and Eichengreen (1992) that the Depression was propagated worldwide from the U.S. through the Gold Standard. However, I cannot separately identify the purely domestic short-run effects of common disturbances from the effects due to transmission of short-run U.S. responses to the same disturbances. Consequently, while my results do not support it, I cannot *rule out* a signficant role for a Gold Standard or export demand transmitted contraction originating in the aggregate supply collapse.

The implications of my results for Bernanke's (1983) hypothesis are unclear. Bernanke argued that bank failures, and financial crises more generally, caused a protracted 'monetary' non-neutrality due to the investment and consequent supply-side effects of the decline in efficient credit intermediation arrangements. Since I cannot isolate different sources of supply disturbances with my empirical model, any permanent output effects of credit market disruptions during the 1931-1933 era will be captured by the identified supply shocks. My finding that there was significant unanticipated deflation in 1930-1931 which could engender bankruptcies and financial crises, as both Bernanke (1983) and Fisher (1933) have argued lends support to this interpretation. The symmetry in output collapse across the two economies must then, however, be accounted for by similarity in credit market disturbances for Canada and the U.S., a hypothesis which Haubrich rejects.

My results provide dramatic support for hypotheses, such as those of Fisher (1933), Bernstein (1987) and Safarian (1959) that emphasize secular factors in explaining the Depression. Moreover, they indicate that these factors were continent-wide, and potentially global, providing a rationalization for the synchronicity of the international output collapse. This suggests a promising alternative to traditional views that the worldwide Depression simply reflected transmission of idiosyncratic U.S. disturbances to the rest of the world.

While the exceptionally close geographic and economic ties between Canada and the U.S. imply that my results may not extend to the European Depression experience, they do challenge future research to account more fully for common, secular factors in the global output collapse.

Table 2.1 : Data Sources and Notation

All series are monthly, and deterministically seasonally adjusted except the nominal exchange rate series which has no significant seasonal component. Logarithms are used throughout the analysis except in the data plots presented in Figures 2.1a-2.1f which employ an index number of the level of each series, setting 1935-1939=100. All series which are expressed as indexes in *raw* form (industrial production and price variables) are re-indexed to a 1935-1939 =100 base prior to application of the logarithmic transformation.

- $\mathbf{y_c}$ is the log of industrial production index, Canada, (1935-1939=100) from the *Monthly Review of Business Statistics*, published in various issues by the Dominion Bureau of Statistics, Canada
- $\mathbf{y_{us}}$ is the log of industrial production index, U.S., (1935-1939=100) from the Federal Reserve Board of Governors, U.S.
- $\mathbf{m_c}$ is the log of M1 money stock, Canada, from Metcalfe, Redish and Shearer (1993)
- $\mathbf{m_{us}}$ is the log of M1 money stock, U.S., from Friedman and Schwartz (1970), Table 1
- $\mathbf{p_c}$ is the log of wholesale price index, Canada, (1935-1939=100), published in various issues of *Prices and Price Indexes* by the Dominion Bureau of Statistics
- $\mathbf{p_{us}}$ is the log of wholesale price index, U.S., (1935-1939=100), from various issues of *Statistical Abstract of the U.S.*, published by the U.S. Department of Commerce
- **e** is the log of (noon) nominal spot exchange rate in \$C / \$U.S., from various issues of *Prices and Price Indexes*, published by the Dominion Bureau of Statistics. Specifically, the monthly average of closing rates in Montreal.
- $\mathbf{v_c}$ is the log of velocity in Canada, computed as $\mathbf{y_c}+\mathbf{p_c}-\mathbf{m_c}$ with data sources as above
- $\mathbf{v_{us}}$ is the log of velocity in Canada, computed as $\mathbf{y_{us}}+\mathbf{p_{us}}-\mathbf{m_{us}}$ with data sources as above

Table 2.2 : Descriptive Statistics

Table 2.2a : Descriptive Statistics (Log Levels)

Series	Sample	Date of Minimum Value	Date of Maximum Value	Standard Deviation	Mean	Correlation with y_c
y_c	25:01-39:12	33:02	29:01	0.182	4.479	1.000
	25:01-28:12	25:04	28:05	0.132	4.452	1.000
	29:01-33:12	33:02	29:01	0.233	4.395	1.000
	34:01-39:12	34:02	39:12	0.122	4.566	1.000
y_{us}	25:01-39:12	32:07	39:12	0.192	4.484	0.857
	25:01-28:12	25:06	28:10	0.044	4.542	0.792
	29:01-33:12	32:07	29:05	0.235	4.357	0.947
	34:01-39:12	34:11	39:12	0.160	4.550	0.865
m_c	25:01-39:12	33:01	39:12	0.139	6.535	0.843
	25:01-28:12	25:07	28:06	0.082	6.493	0.857
	29:01-33:12	33:01	29:12	0.144	6.468	0.907
	34:01-39:12	34:01	39:12	0.146	6.620	0.894
$(m_{us} + e)$	25:01-39:12	33:11	39:12	0.134	7.887	0.661
	25:01-28:12	28:04	25:01	0.017	7.868	0.611
	29:01-33:12	33:11	29:10	0.085	7.807	0.610
	34:01-39:12	34:01	39:12	0.164	7.966	0.899
p_c	25:01-39:12	33:02	25:02	0.150	4.669	0.352
	25:01-28:12	28:12	25:01	0.028	4.861	-0.741
	29:01-33:12	33:02	29:08	0.150	4.606	0.941
	34:01-39:12	34:01	37:07	0.055	4.592	0.730
$(p_{us} + e)$	25:01-39:12	33:01	25:03	0.121	4.656	0.325
	25:01-28:12	27:04	25:03	0.035	4.811	-0.771
	29:01-33:12	33:01	29:07	0.115	4.601	0.888
	34:01-39:12	34:03	39:12	0.055	4.600	0.720

Table 2.2b : Cross-Correlation Matrix (Log Levels)

Series	y_c	y_{us}	m_c	$(m_{us} + e)$	p_c	$(p_{us}+e)$
y_c	1.00	*	*	*	*	*
y_{us}	0.86	1.00	*	*	*	*
m_c	0.84	0.74	1.00	*	*	*
$(m_{us} + e)$	0.66	0.67	0.88	1.00	*	*
p_c	0.35	0.56	0.18	0.16	1.00	*
$(p_{us} + e)$	0.32	0.57	0.17	0.22	0.97	1.00

Table 2.2c : Descriptive Statistics (Log Differences)

Series	Sample	Date of Minimum Value	Date of Maximum Value	Standard Deviation	Mean
Δ y_c	25:02-39:12	31:06	29:01	0.060	0.003
	25:02-29:01	26:12	29:01	0.072	0.012
	29:02-34:01	31:06	30:01	0.066	-0.008
	34:02-39:12	35:03	34:05	0.042	0.007
Δ y_{us}	25:02-39:12	29:12	33:05	0.045	0.021
	25:02-29:01	27:11	29:01	0.025	0.004
	29:02-34:01	29:12	33:05	0.058	-0.007
	34:02-39:12	37:11	34:12	0.041	0.008
Δ m_c	25:02-39:12	30:01	25:12	0.035	0.003
	25:02-29:01	28:01	25:12	0.036	0.004
	29:02-34:01	30:01	33:12	0.034	-0.004
	34:02-39:12	39:04	35:03	0.033	0.008
Δ $(m_{us} + e)$	25:02-39:12	29:11	39:09	0.022	0.003
	25:02-29:01	28:06	28:12	0.011	0.001
	29:02-34:01	29:11	33:12	0.029	-0.004
	34:02-39:12	35:09	39:09	0.019	0.010
Δ p_c	25:02-39:12	30:12	39:09	0.013	-0.001
	25:02-29:01	25:04	25:11	0.010	-0.002
	29:02-34:01	30:12	33:07	0.015	-0.005
	34:02-39:12	38:08	39:09	0.014	0.002
Δ $(p_{us} + e)$	25:02-39:12	32:01	39:09	0.018	-0.001
	25:02-29:01	25:04	25:07	0.008	-0.002
	29:02-34:01	32:01	31:10	0.020	-0.005
	34:02-39:12	37:11	39:09	0.019	0.003

Notes :

All series in logarithms and deterministically seasonally adjusted except the nominal exchange rate which has no significant seasonal component. Data analysis for the U.S. price level and M1 money stock shows that these variables have properties qualitatively similar to their exchange rate adjusted counterparts, and so only the latter results are reported in the interest of clarity.

Table 2.3 : Non-Stationarity Test Results

Table 2.3a : Tests For Non-stationarity (Log Levels)

Series	$\hat{Z}_{\alpha_\tau}$	$\hat{Z}_{t_\tau}$	$\hat{T}_\tau(1)$	$\hat{T}_\tau(4)$	$\hat{T}_\tau$ (6)
y_c	-6.21	-1.72	-1.57	-1.53	-1.70
y_{us}	-5.53	-1.45	-1.66	-1.54	-1.13
m_c	-2.29	-0.72	-0.92	-0.36	-0.40
$(m_{us}+e)$	1.05	0.39	0.70	-0.06	-0.10
p_c	-1.28	-0.59	-0.73	-0.10	-1.25
$(p_{us}+e)$	-2.52	0.79	-0.97	-0.91	-1.02
v_c	-9.45	-2.23	-2.10	-1.69	-1.89
v_{us}	-8.23	-1.97	-2.13	-2.13	-1.57

Table 2.3b : Tests For Non-Stationarity (Log Differences)

Series	$\hat{Z}_{\alpha_\tau}$	$\hat{Z}_{t_\tau}$	$\hat{T}_\tau(1)$	$\hat{T}_\tau(4)$	$\hat{T}_\tau$ (6)
Δ y_c	-224.63***	-18.50***	-11.78***	-5.98***	-4.70***
Δ y_{us}	-123.97***	-9.780***	-8.18***	-6.56***	-4.97***
Δ m_c	-177.79***	-15.46***	-12.27***	-5.94***	-4.63***
Δ $(m_{us}+e)$	-203.51***	-13.72***	-7.270***	-5.61***	-4.13***
Δ p_c	-117.53***	-9.350***	-7.20***	-3.85**	-3.27*
Δ $(p_{us}+e)$	-138.74***	-10.67***	-8.20***	-5.55***	-3.94**
Δ v_c	-206.31***	-18.64***	-13.24***	-6.48***	-5.23***
Δ v_{us}	-129.87***	-10.10***	-7.990***	-6.32***	-4.83***

Notes :

* denotes significance at the 15% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level. $\hat{Z}_{\alpha_\tau}$ and $\hat{Z}_{t_\tau}$ are computed values of the Phillips (1987) statistics for the null hypothesis that the series is non-stationary around a first order polynomial time trend and constant term. Four autocovariance terms are used to compute the spectrum at frequency zero. $\hat{T}_{\tau(k)}$ is the computed value of the Said and Dickey (1984) (Augmented Dickey-Fuller (1979, 1981)) statistic for the same null hypothesis, where k is the number of lagged first difference terms included in the test regression. Critical values tabulated in Phillips and Ouliaris (1990), Fuller (1976) and from Ouliaris (1991). The time series properties of the U.S. money supply and price level series are qualitatively the same as those for their exchange rate adjusted counterparts and so only the latter are reported.

Table 2.4 : Cointegration Test Results

Table 2.4a : Univariate Cointegration Tests

Dependent Variable	Independent Variable	$\hat{Z}_{\alpha_\mu}$	$\hat{Z}_{t_\mu}$	$\hat{T}_\mu(1)$	$\hat{T}_\mu$ (4)	$\hat{T}_\mu$ (6)
m_c	$(m_{us}+e)$	-22.71**	-3.59**	-3.52**	-2.91	-3.18*
p_c	$(p_{us}+e)$	-22.39**	-3.25**	-3.17*	-3.28*	-2.78
v_c	v_{us}	-58.88***	-6.05***	-4.56***	-4.16***	-4.43***
m_c	p_c	-0.05	-0.02	-0.31	0.35	0.23
m_{us}	p_{us}	-2.20	-1.30	1.60	0.70	0.69
$(m_c - p_c)$	y_c	-2.75	-0.25	-1.38	-0.83	-1.07
$(m_{us}-p_{us})$	y_{us}	-2.75	-1.21	-0.21	-0.44	-0.16
(m_c-p_c)	$(m_{us}-p_{us})$	-26.33***	-3.96**	-3.76**	-2.90*	-2.96*

Table 2.4b : Univariate Cointegration Tests (Constrained Coefficients)

Series	$\hat{Z}_{\alpha_\mu}$	$\hat{Z}_{t_\mu}$	$\hat{T}_\mu(1)$	$\hat{T}_\mu$ (4)	$\hat{T}_\mu(6)$
(y_c-y_{us})	-29.16***	-4.28***	-4.01***	-3.54***	-3.67***
$(m_c-m_{us}-e)$	-23.07***	-3.58***	-3.46**	-2.89**	-3.16**
$(p_c-p_{us}-e)$	-11.47*	-2.39*	-2.26	-2.80*	-2.41*
(v_c-v_{us})	-51.03***	-5.57***	-4.41***	-4.48***	-4.67***
(m_c-p_c)	-1.48	-0.81	-1.03	-0.63	-0.85
$(m_{us}-p_{us})$	0.43	0.25	0.34	-0.00	-0.21
$(m_c-p_c)-(m_{us}-p_{us})$	-23.83***	-3.85***	-3.70***	-2.89**	-2.99**

Table 2.4c : Multivariate Cointegration Tests

Series	$\hat{J}_{t_\mu}$ (0)	$\hat{J}_{m_\mu}$ (0)	$\hat{J}_{t_\mu}$ (3)	$\hat{J}_{m_\mu}$ (3)
$y_c, m_c, p_c, y_{us}, (m_{us}+e), (p_{us}+e)$	121.0***	54.80***	18.14	11.71
y_c, y_{us}	21.89**	20.00***	n/a	n/a
$m_c, (m_{us}+e)$	12.50*	11.50*	n/a	n/a
$p_c, (p_{us}+e)$	19.86**	16.94**	n/a	n/a
v_c, v_{us}	41.92***	18.37**	n/a	n/a
m_c, p_c	3.800	3.800	n/a	n/a
m_{us}, p_{us}	3.800	3.600	n/a	n/a
$(m_c-p_c), y_c$	5.200	4.700	n/a	n/a
$(m_{us}-p_{us}), y_{us}$	4.600	3.900	n/a	n/a
$(m_c-p_c), (m_{us}-p_{us})$	13.52*	13.50*	n/a	n/a

Table 2.4 cont.

Table 2.4d : Multivariate Cointegrating Vector Estimates

Series	FM Estimate	SJ Estimate
y_c, y_{us}	(1, -0.85)	(1, -0.96)
m_c, $(m_{us}+e)$	(1, -0.95)	(1, -1.06)
p_c, $(p_{us}+e)$	(1, -1.21)	(1, -1.26)
v_c, v_{us}	(1, -0.85)	(1, -0.93)
(m_c-p_c), $(m_{us}-p_{us})$	(1, -1.11)	(1, -1.11)

Notes :

Notes for **Tables 2.4a** and **2.4b** as for **Tables 2.3a** and **2.3b**. The test statistics for the unconstrained coefficient tests are applied to the residuals from the cointegrating regressions of the Dependent Variable on the Independent Variable in **Table 2.4a**, as in non-stationarity tests in **Table 2.4b**. I report results for the case in which a constant term, μ, is included in the test regressions. The cointegration results for the U.S. money supply and price level series are qualitatively similar to those for their exchange rate adjusted counterparts and so only the latter are reported. In **Table 2.4c**, $\hat{J}_{t_\mu}$(K) and $\hat{J}_{m_\mu}$(K) are computed values of the Johansen and Juselius (1990) trace and maximum eigenvalue test statistics for the null hypothesis that there are K cointegrating vectors in the specified system. Critical values from Johansen and Juselius (1990) and Ouliaris (1991). Column 2 in **Table 2.4d** gives the Phillips-Hansen Fully Modified estimates of the cointegrating vectors. Column 3 gives normalized estimates derived from those generated from the Johansen tests for **Table 2.4c**.

Table 2.5 : VAR Results (1925:1-1939:12)

Table 2.5a : VAR F-statistics

Variable/ Equation	Δ y_c	Δ m_c	Δ p_c	(y_c-y_{us})	(m_c-m_{us}-e)	(p_c-p_{us}-e)	R^2
Δ y_c	2.68**	2.35**	0.03	6.09***	2.98**	1.16	0.27
Δ m_c	3.47***	2.52**	2.91**	5.05***	10.37***	5.72***	0.35
Δ p_c	1.80*	2.00*	3.94***	1.63*	0.63	2.77**	0.22
(y_c-y_{us})	8.15***	1.92*	0.83	49.97***	1.98*	0.62	0.75
(m_c-m_{us}-e)	2.17*	2.26*	2.04*	4.69***	49.76***	4.80***	0.74
(p_c-p_{us}-e)	1.07	0.77	0.34	1.59*	1.26	180.34***	0.89

Notes :

The rows give value of F-statistics for each equation in the VAR system. This statistic evaluates the null hypothesis that the block of lags pertaining to the variable in each column is zero. * denotes rejection of the null at 20%, ** at 5% and *** at 1% . Final column gives adjusted R^2 for the equation.

Table 2.6 : Structural Model (1925:1-1939:12)

Table 2.6a : Forecast Error Variance Decomposition For Canadian Output (y_c)

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	28.7 (18.4)	7.3 (13.3)	2.3 (10.5)	33.1 (19.5)	28.7 (26.7)
3 months	49.0 (20.5)	5.4 (11.7)	2.2 (10.0)	23.3 (15.0)	24.1 (20.9)
6 months	71.1 (22.3)	3.0 (10.2)	1.5 (9.3)	12.0 (12.6)	12.4 (15.2)
12 months	86.6 (22.3)	1.4 (10.5)	0.8 (8.9)	5.4 (10.8)	5.8 (10.6)
24 months	93.9 (18.7)	0.6 (10.1)	0.4 (7.6)	2.5 (7.2)	2.6 (6.6)
36 months	96.0 (15.7)	0.4 (9.2)	0.2 (6.3)	1.6 (5.2)	1.7 (4.8)
120 months	98.9 (6.0)	0.1 (4.3)	0.1 (2.2)	0.5 (1.2)	0.5 (1.4)

Table 2.6b : Forecast Error Variance Decomposition For U.S. Output (y_{us})

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	62.9 (25.0)	20.0 (18.3)	0.3 (10.9)	16.8 (19.2)	0.0 (0.0)
3 months	77.4 (24.0)	7.4 (13.4)	0.2 (10.2)	13.4 (17.8)	1.6 (3.6)
6 months	87.9 (23.1)	3.2 (11.7)	0.2 (9.7)	7.8 (14.9)	0.9 (4.3)
12 months	92.4 (21.4)	1.6 (11.2)	0.2 (9.1)	5.4 (10.9)	0.4 (3.3)
24 months	95.3 (18.6)	0.9 (10.4)	0.1 (8.0)	3.4 (7.3)	0.2 (2.7)
36 months	96.6 (16.2)	0.6 (9.6)	0.1 (7.0)	2.4 (5.5)	0.2 (2.2)
120 months	98.8 (7.8)	0.2 (5.7)	0.0 (2.8)	0.8 (1.8)	0.1 (0.8)

Table 2.6 cont.

Table 2.6c : Forecast Error Variance Decomposition For Canadian Money (m_c)

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	11.3 (14.5)	31.7 (18.9)	3.8 (12.5)	5.4 (18.1)	47.9 (24.9)
3 months	12.3 (12.9)	59.6 (19.9)	1.8 (9.1)	3.8 (12.3)	22.5 (16.2)
6 months	22.1 (15.1)	61.9 (20.1)	1.2 (7.9)	2.4 (10.4)	12.4 (13.2)
12 months	26.7 (16.8)	65.3 (20.6)	0.6 (7.5)	1.2 (7.8)	6.2 (9.9)
24 months	29.2 (18.9)	66.8 (21.4)	0.3 (6.5)	0.6 (5.3)	3.1 (6.5)
36 months	29.8 (20.2)	67.5 (21.9)	0.2 (5.5)	0.4 (3.9)	2.1 (4.8)
120 months	30.6 (23.7)	68.6 (23.8)	0.1 (2.2)	0.1 (1.0)	0.6 (1.5)

Table 2.6d : Forecast Error Variance Decomposition For U.S. Money ($m_{us}+e$)

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	56.7 (26.3)	40.4 (25.7)	2.9 (18.6)	0.0 (0.0)	0.0 (0.0)
3 months	48.0 (23.7)	47.7 (24.4)	3.3 (17.1)	0.8 (1.8)	0.1 (3.1)
6 months	45.9 (22.6)	51.0 (24.0)	1.7 (15.4)	1.1 (2.7)	0.2 (4.5)
12 months	42.7 (21.8)	55.3 (23.5)	0.8 (13.0)	0.8 (2.9)	0.3 (4.9)
24 months	38.4 (20.9)	60.5 (22.4)	0.4 (9.3)	0.5 (2.9)	0.2 (3.9)
36 months	36.3 (21.1)	62.9 (22.3)	0.3 (7.2)	0.4 (2.5)	0.1 (3.2)
120 months	32.8 (23.8)	67.0 (23.9)	0.1 (2.3)	0.1 (0.8)	0.0 (1.0)

Table 2.6 cont.

Table 2.6e : Forecast Error Variance Decomposition For Canadian Prices (p_c)

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	1.4 (7.8)	16.5 (11.2)	34.3 (20.9)	9.8 (18.1)	38.0 (23.5)
3 months	11.2 (12.2)	20.5 (12.9)	32.2 (20.0)	9.3 (17.6)	26.9 (20.6)
6 months	20.1 (14.9)	26.7 (15.0)	23.6 (17.8)	10.6 (16.5)	18.3 (17.6)
12 months	31.4 (17.3)	26.6 (15.6)	23.6 (17.4)	10.3 (10.8)	8.0 (12.0)
24 months	35.7 (20.1)	25.9 (16.3)	28.1 (17.8)	7.1 (7.5)	3.2 (7.0)
36 months	35.1 (21.6)	26.5 (17.0)	31.3 (18.2)	5.1 (5.1)	2.0 (5.0)
120 months	29.9 (24.7)	29.2 (19.1)	38.9 (19.5)	1.4 (1.2)	0.5 (1.4)

Table 2.6f : Forecast Error Variance Decomposition For U.S. Prices (p_{us}+e)

Forecast Horizon	Supply Shock	Money Shock	Velocity Shock	U.S. Transitory Shock	Canadian Transitory Shock
1 month	17.6 (19.6)	4.5 (11.2)	75.1 (22.3)	0.4 (9.1)	2.3 (12.4)
3 months	21.9 (19.2)	13.4 (13.3)	63.2 (21.6)	0.7 (8.3)	0.8 (10.3)
6 months	28.0 (19.7)	19.8 (15.0)	50.1 (20.8)	1.6 (8.0)	0.4 (8.8)
12 months	30.9 (21.2)	24.3 (16.7)	43.0 (20.8)	1.5 (6.2)	0.3 (6.7)
24 months	31.2 (22.7)	26.7 (17.7)	41.0 (20.7)	1.0 (4.2)	0.1 (4.8)
36 months	30.5 (23.3)	27.7 (18.2)	40.9 (20.6)	0.8 (3.1)	0.1 (3.7)
120 months	28.1 (25.1)	29.8 (19.6)	41.9 (20.5)	0.2 (0.9)	0.0 (1.2)

Notes :

Table 2.7 presents the % forecast error variance attributable to each shock at the forecast horizons indicated. A 0.0 indicates a measured value of less than 0.05%. Standard errors are in parentheses, calculated by Monte Carlo procedures (described in Section

2.5) with results based on 2500 draws. Sensitivity analysis, involving the use of the Fully-Modified cointegrating vector estimates (see **Table 2.5b**) rather than the unit cointegrating vectors and of the non-exchange rate adjusted U.S. money supply and price series, indicates robustness of the model to minor specification changes and we report only structural results for the baseline model. Other results avaliable upon request from the author.

Figure 2.1a: Industrial Production Indices

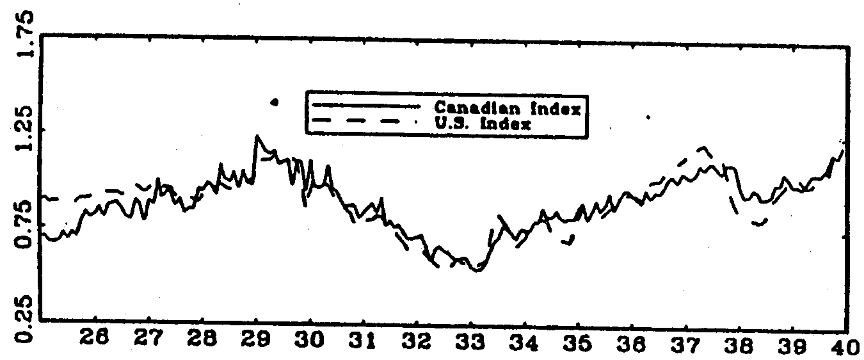


Figure 2.1b: M1 Velocity Indices

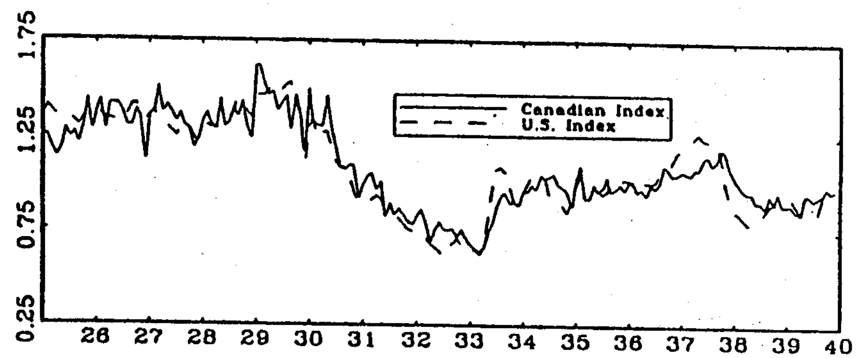


Figure 2.1c: Wholesale Price Indices

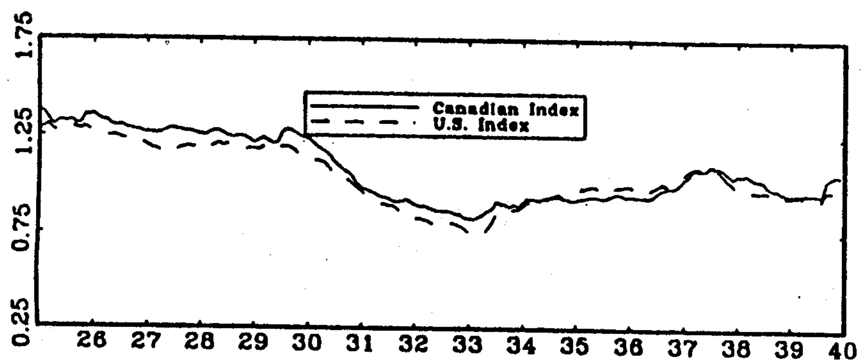


Figure 2.1d: M1 Money Stock Indices

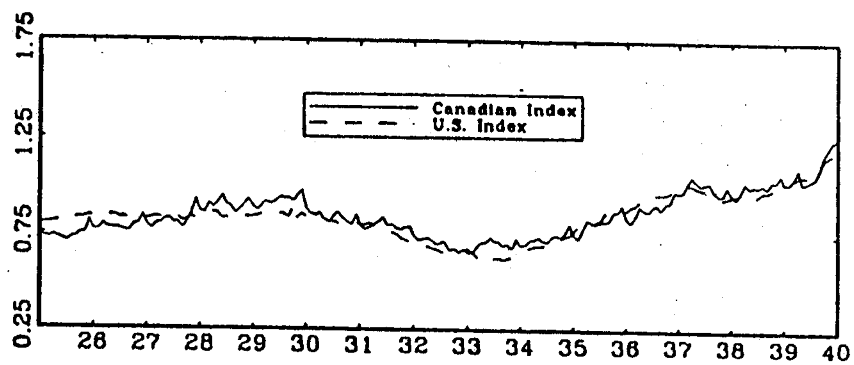


Figure 2.1e: Common Currency Price Indices

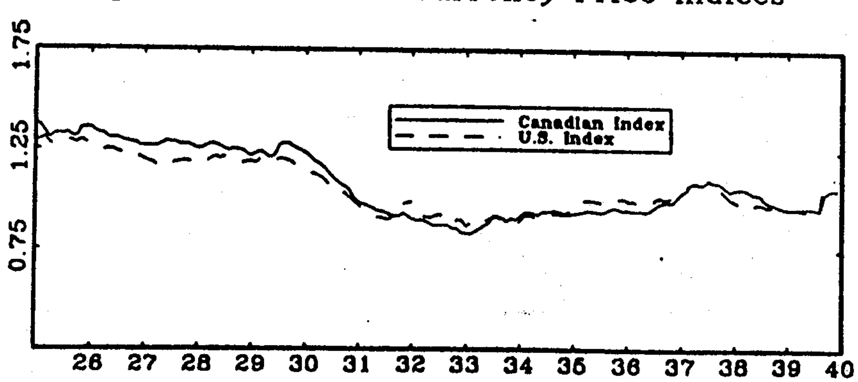


Figure 2.1f: Common Currency M1 Indices

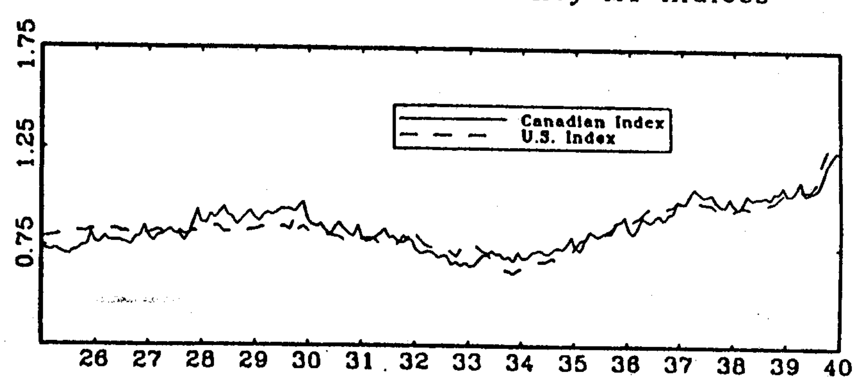


Figure 2.2a: Permanent Supply Shock

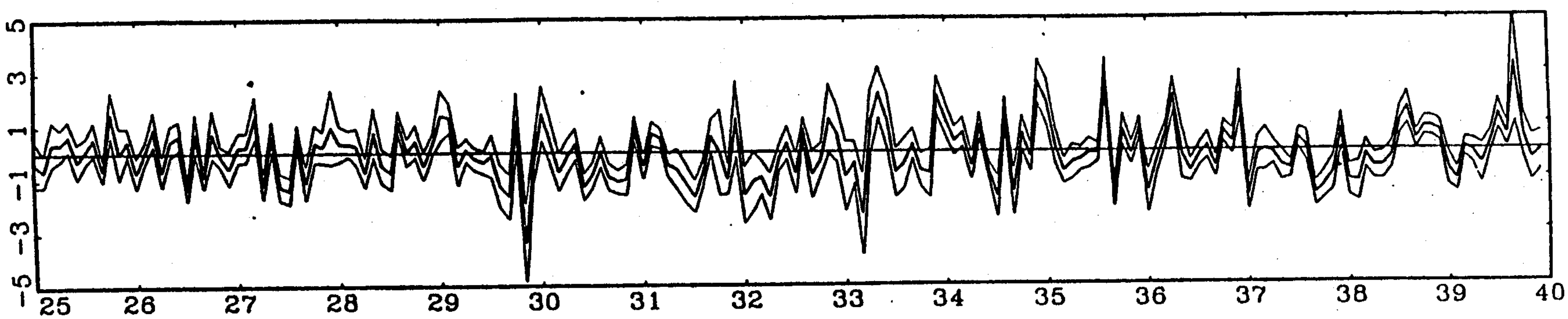


Figure 2.2b: Permanent Money Shock

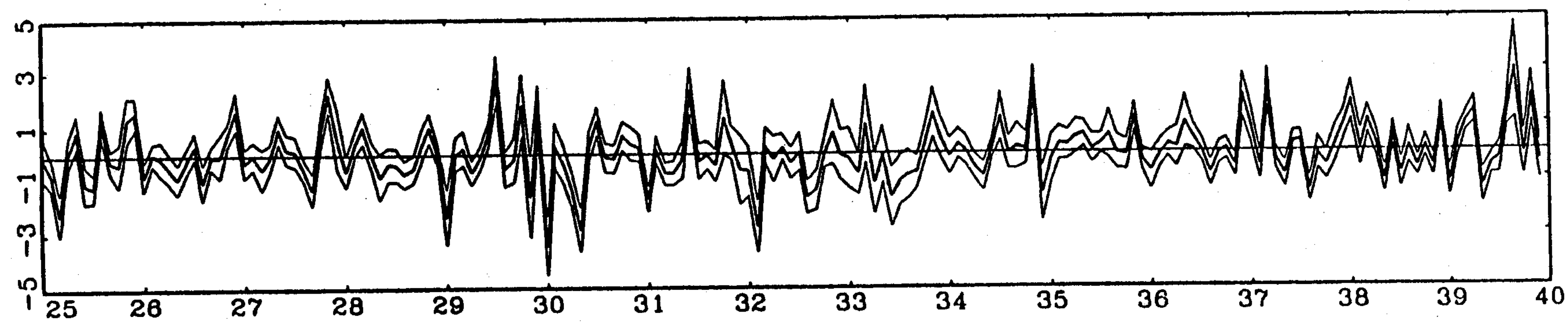


Figure 2.2c: Permanent Velocity Shock

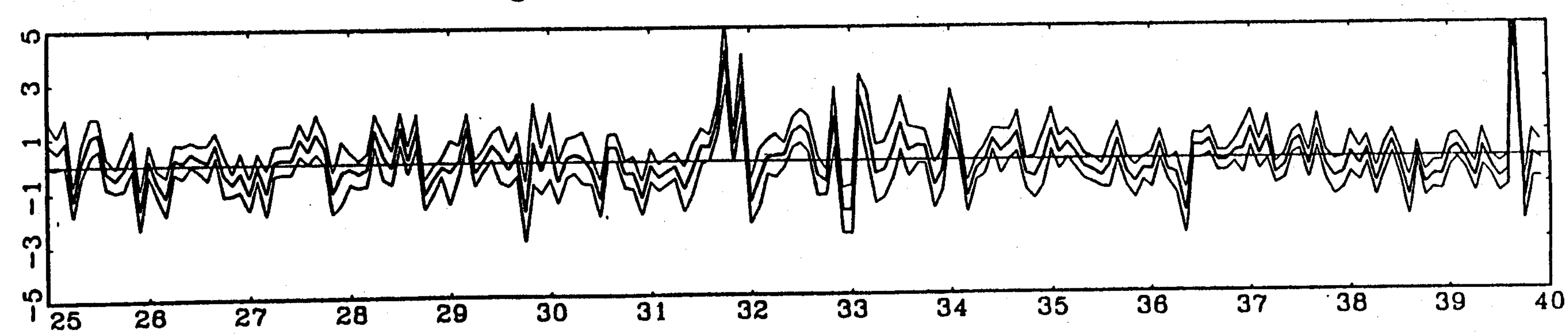


Figure22d: Transitory U.S. Shock

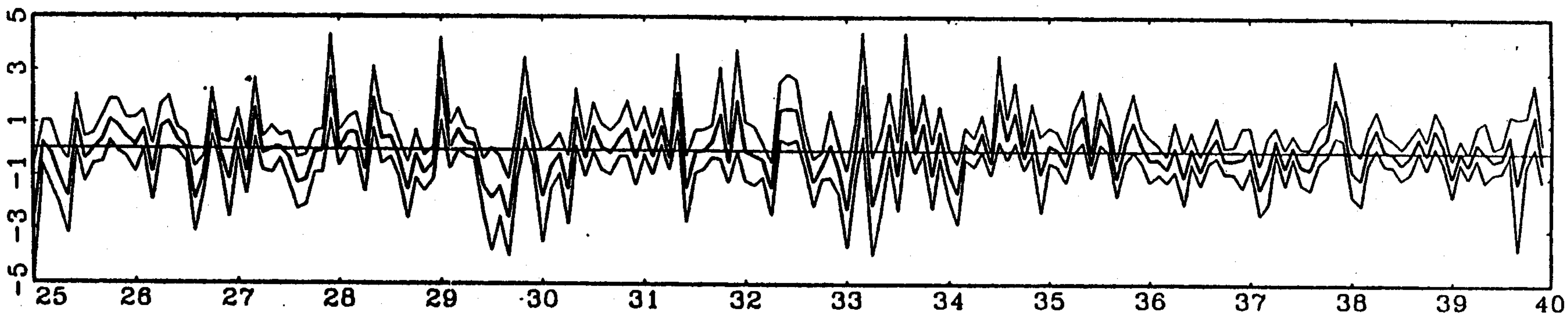


Figure22e: Transitory Canadian Shock

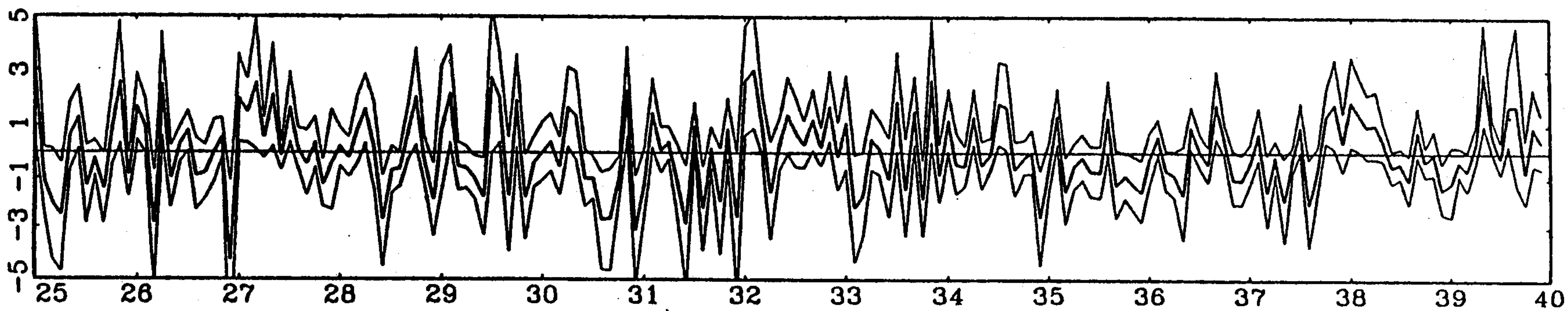


Figure23a: Yc Response to Supply Shock

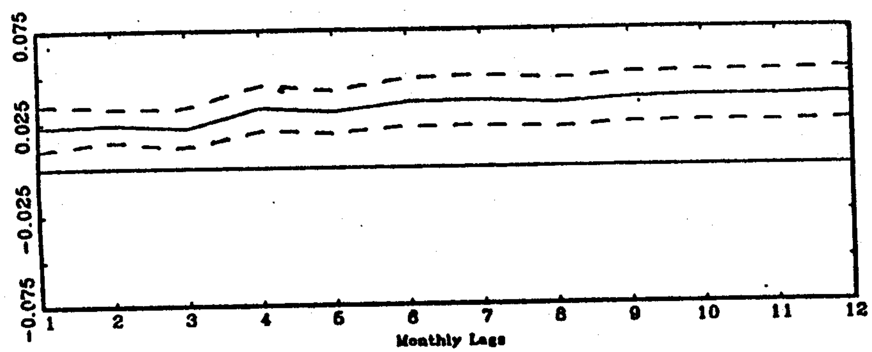


Figure24a: Yus Response to Supply Shock

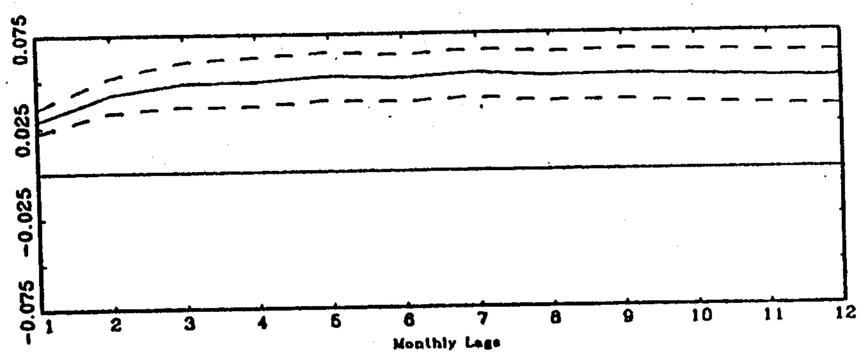


Figure23b: Yc Response to Money Shock

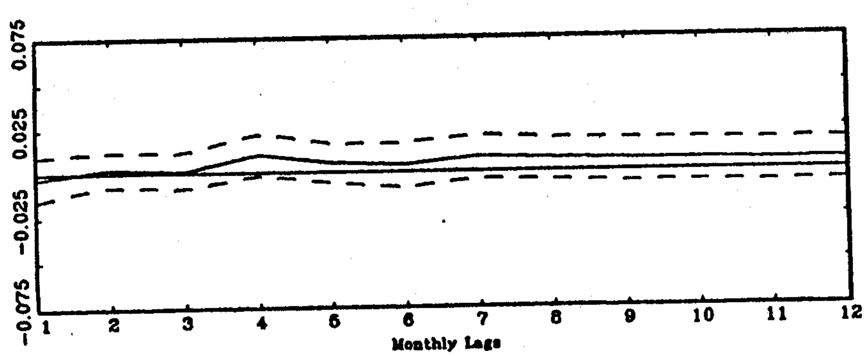


Figure24b: Yus Response to Money Shock

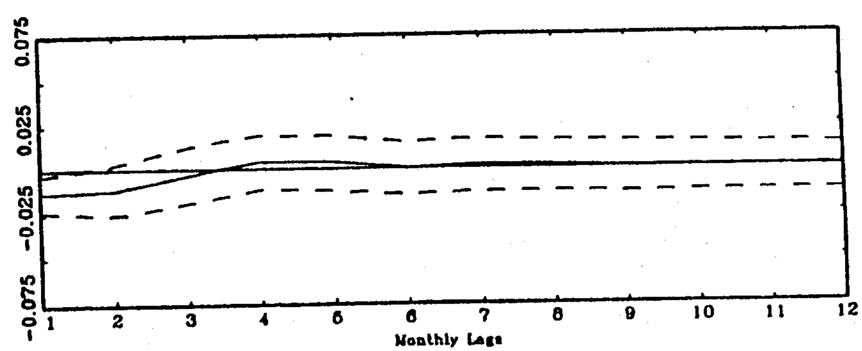


Figure23c: Yc Response to Velocity Shock

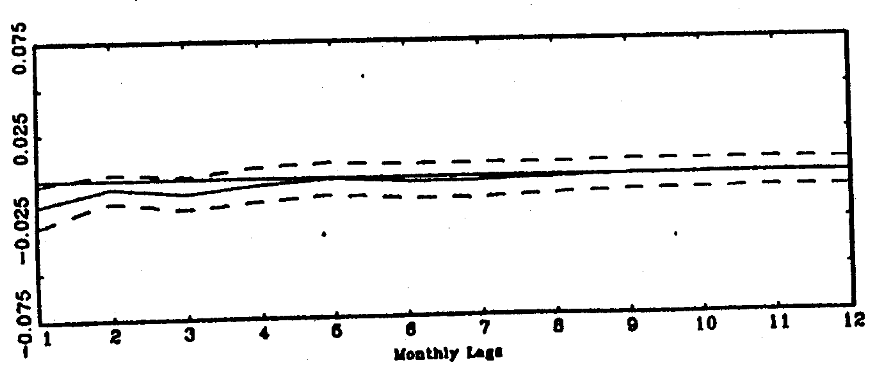


Figure24c: Yus Response to Velocity Shock

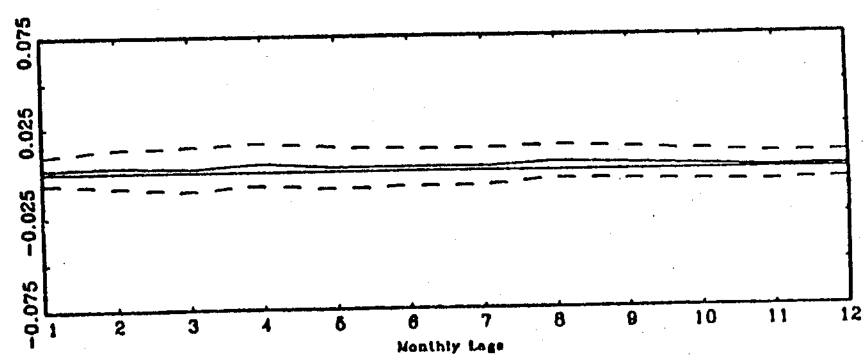


Figure 23d: Yc Response to U.S. Transitory Shock
(bias adjusted)

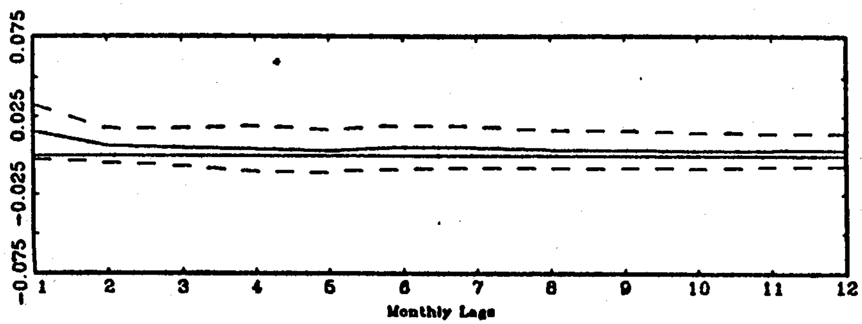


Figure 24d: Yus Response to U.S. Transitory Shock
(bias adjusted)

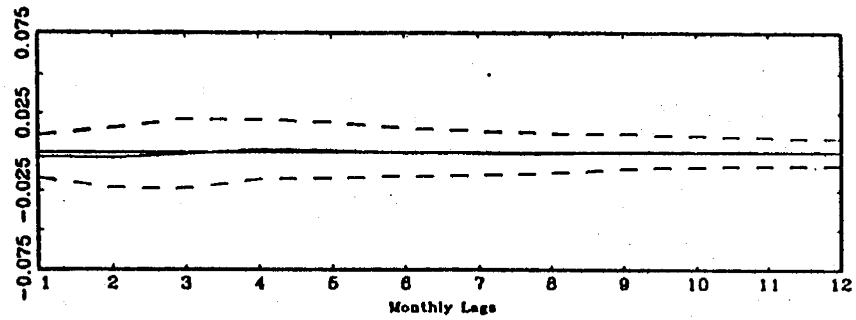


Figure 23e: Yc Response to Cdn. Transitory Shock
(bias adjusted)

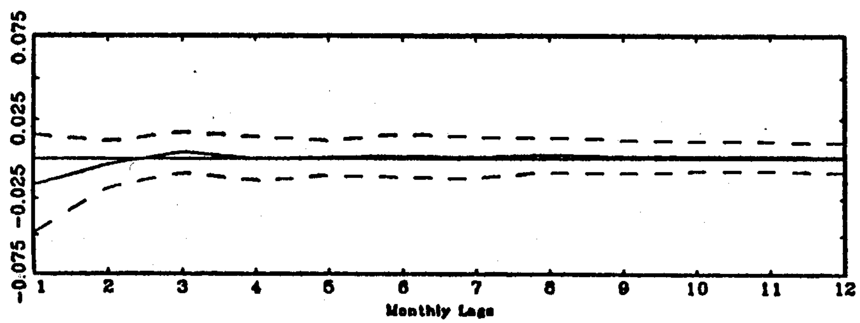


Figure 24e: Yus Response to Cdn. Transitory Shock
(bias adjusted)

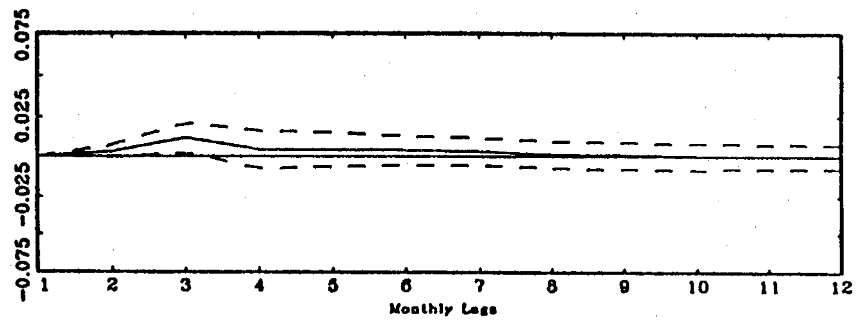


Figure 25a: Mc Response to Supply Shock

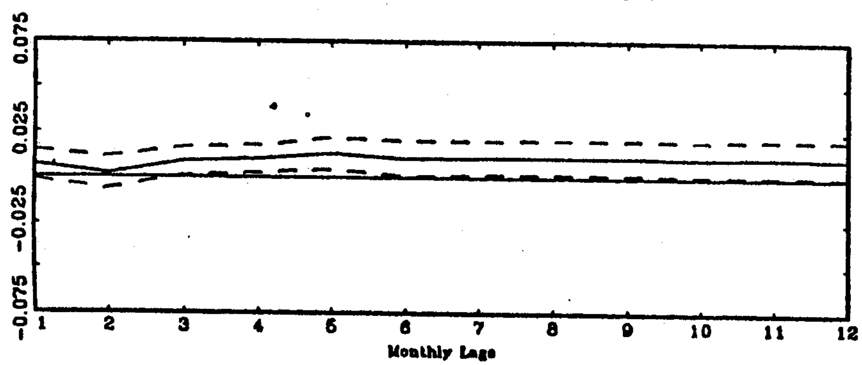


Figure 26a: Mus Response to Supply Shock

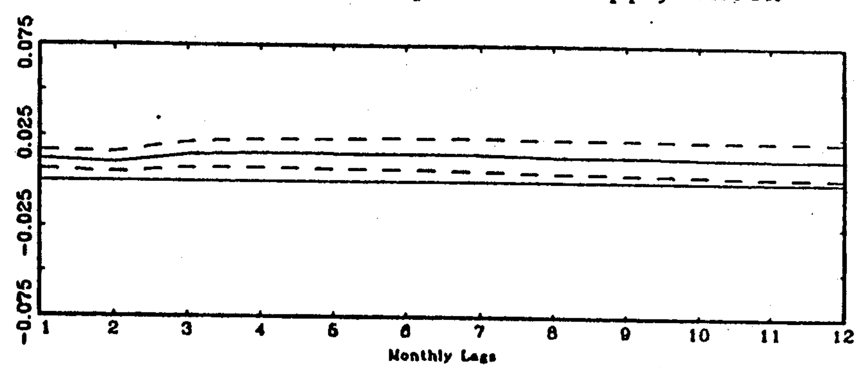


Figure 25b: Mc Response to Money Shock

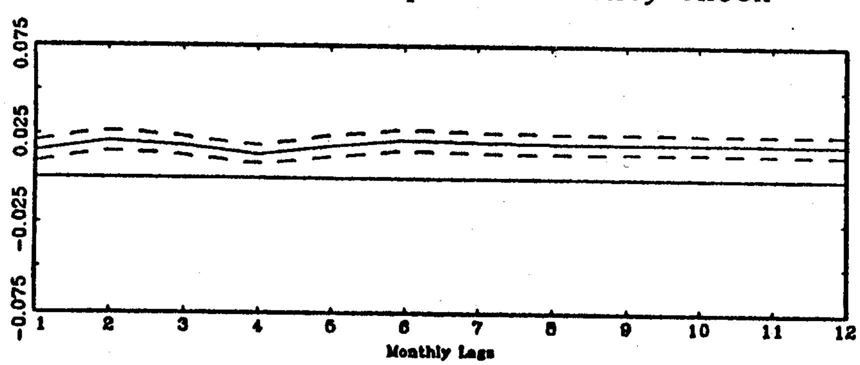


Figure 26b: Mus Response to Money Shock

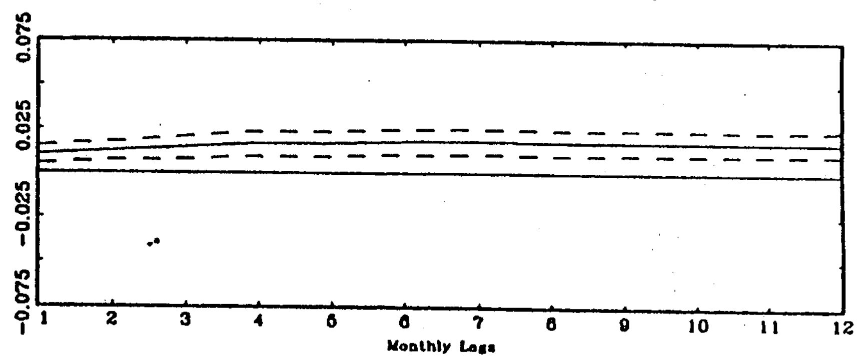


Figure 25c: Mc Response to Velocity Shock

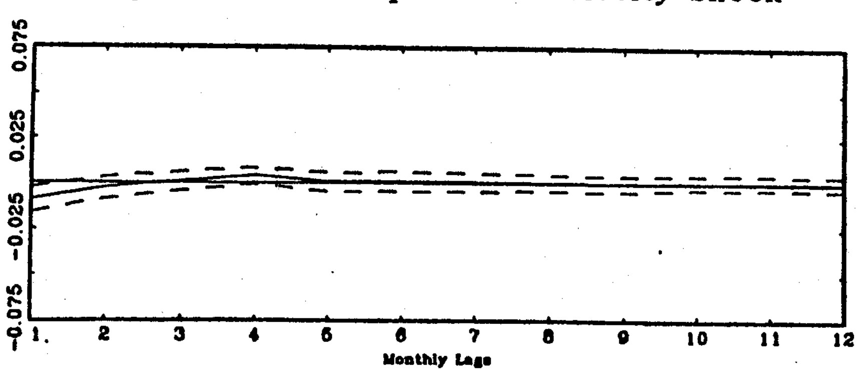


Figure 26c: Mus Response to Velocity Shock

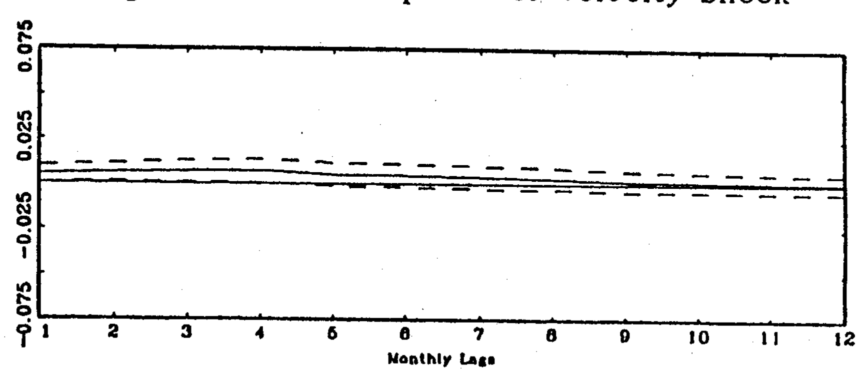


Figure 25d: Mc Response to U.S. Transitory Shock
(bias adjusted)

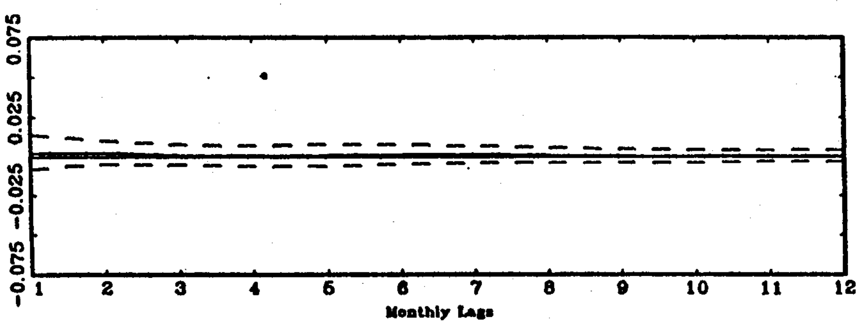


Figure 26d: Mus Response to U.S. Transitory Shock
(bias adjusted)

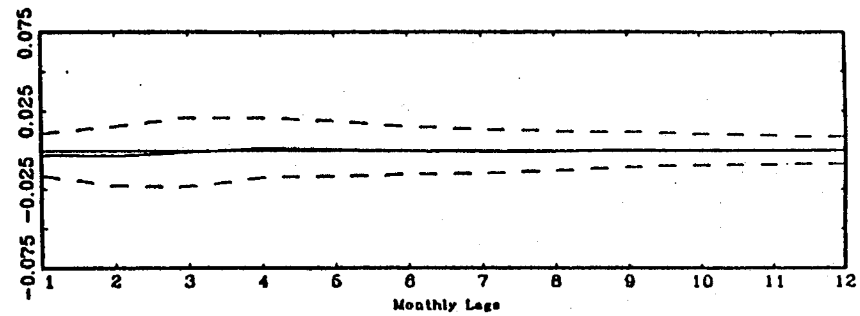


Figure 25e: Mc Response to Cdn. Transitory Shock
(bias adjusted)

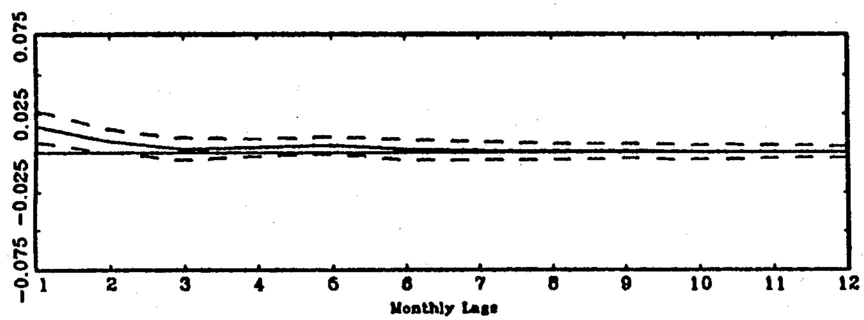


Figure 26e: Mus Response to Cdn. Transitory Shock
(bias adjusted)

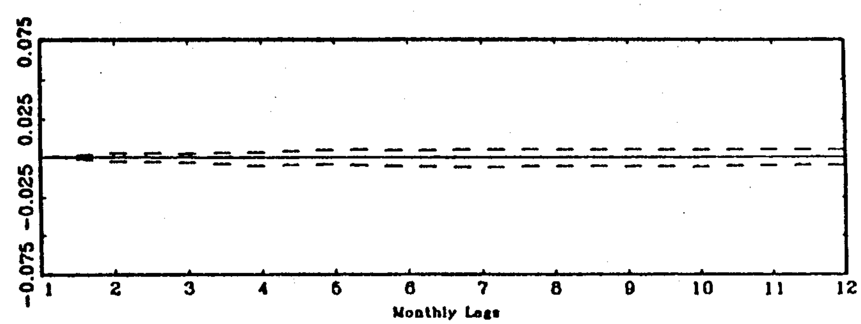


Figure 27a: Pc Response to Supply Shock

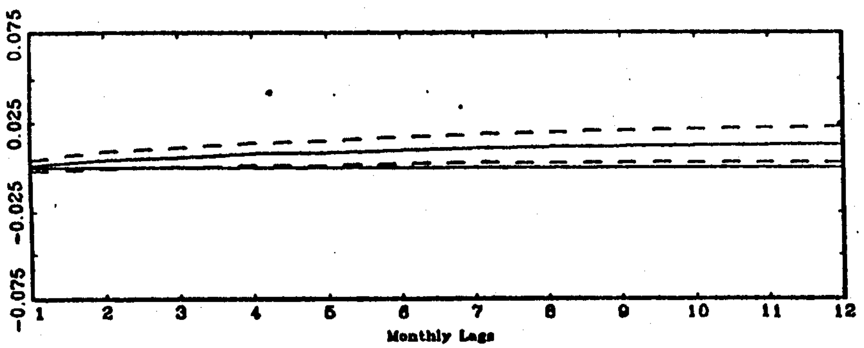


Figure 28a: Pus Response to Supply Shock

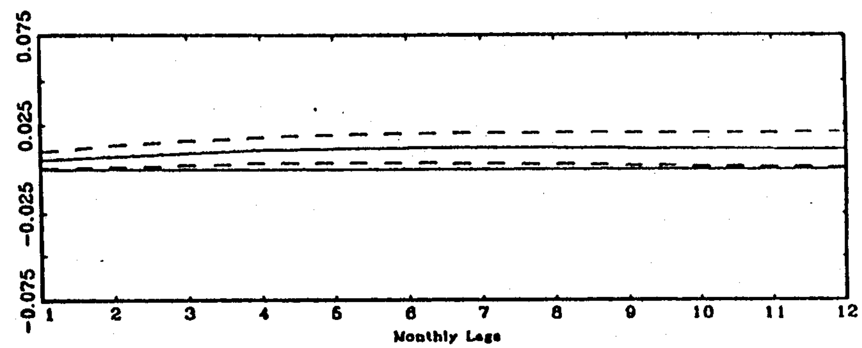


Figure 27b: Pc Response to Money Shock

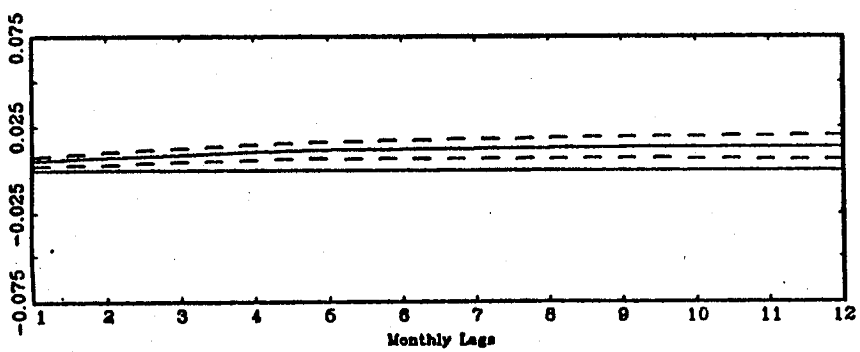


Figure 28b: Pus Response to Money Shock

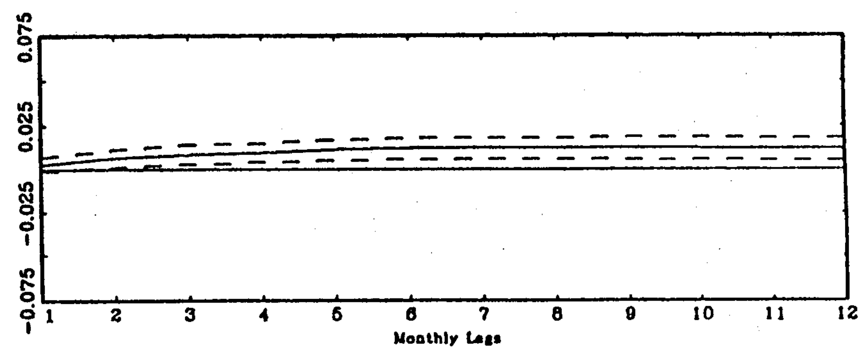


Figure 27c: Pc Response to Velocity Shock

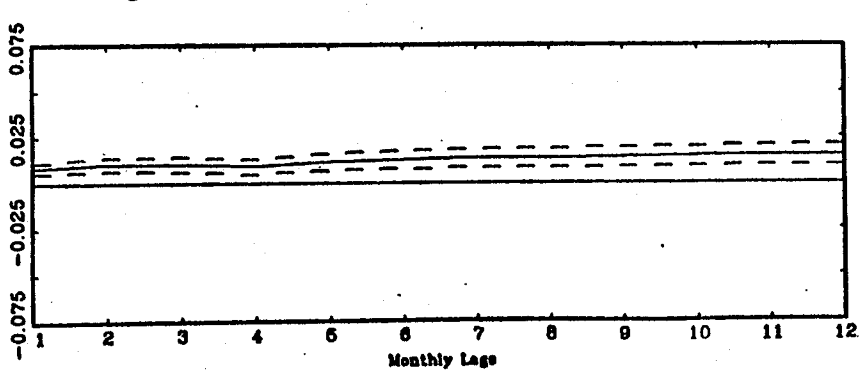


Figure 28c: Pus Response to Velocity Shock

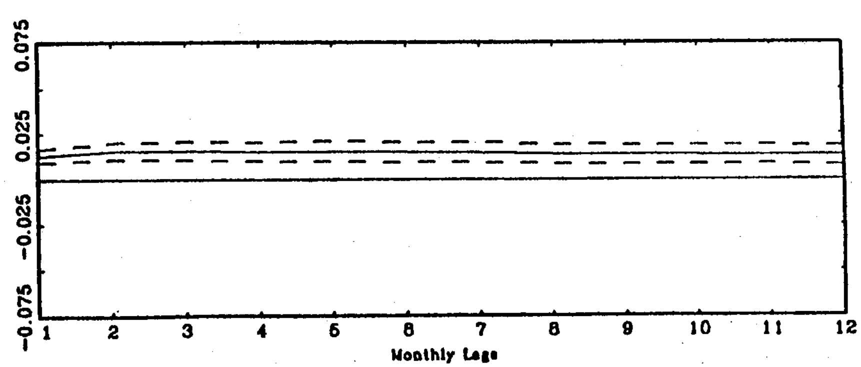


Figure 27d: Pc Response to U.S. Transitory Shock
(bias adjusted)

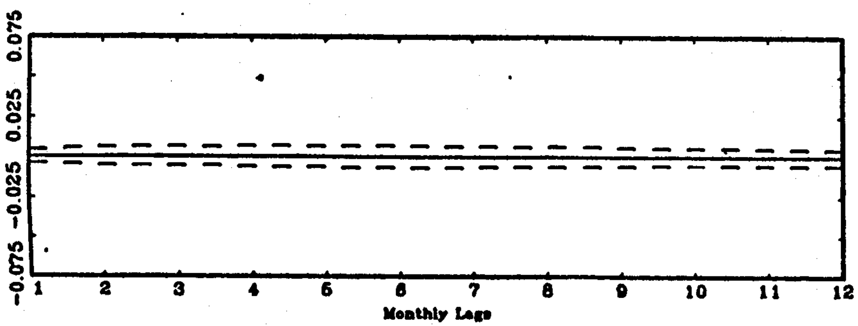


Figure 28d: Pus Response to U.S. Transitory Shock
(bias adjusted)

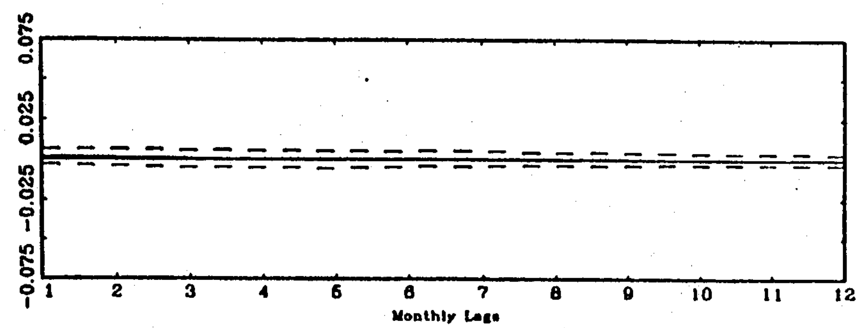


Figure 27e: Pc Response to Cdn. Transitory Shock
(bias adjusted)

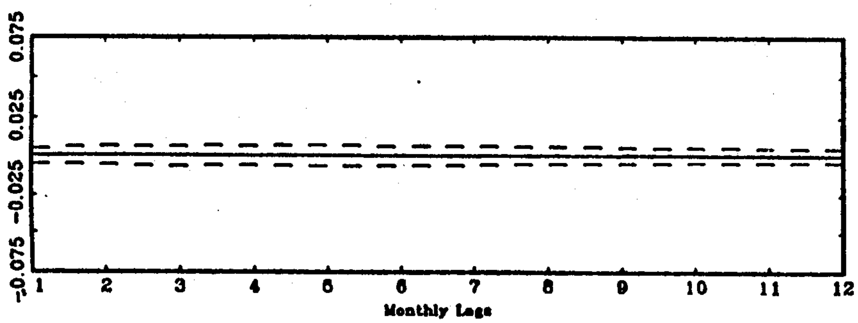


Figure 28e: Pus Response to Cdn. Transitory Shock
(bias adjusted)

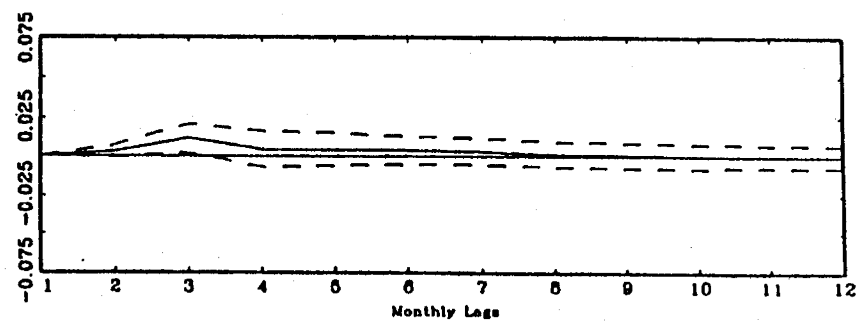


Figure 29a: (Pc−Pus−e) Response to Supply Shock
(bias adjusted)

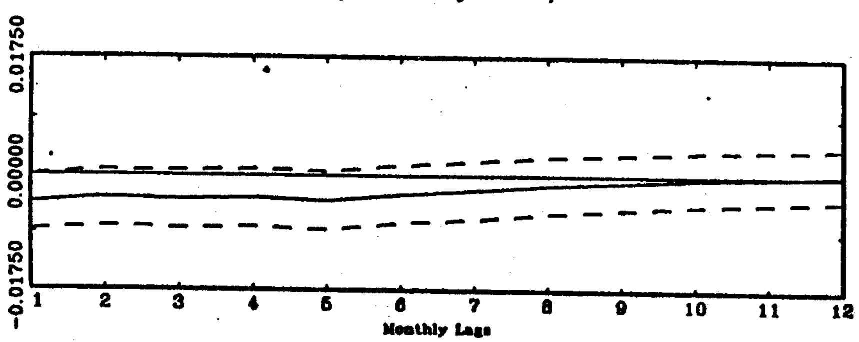


Figure 29b: (Pc−Pus−e) Response to Money Shock

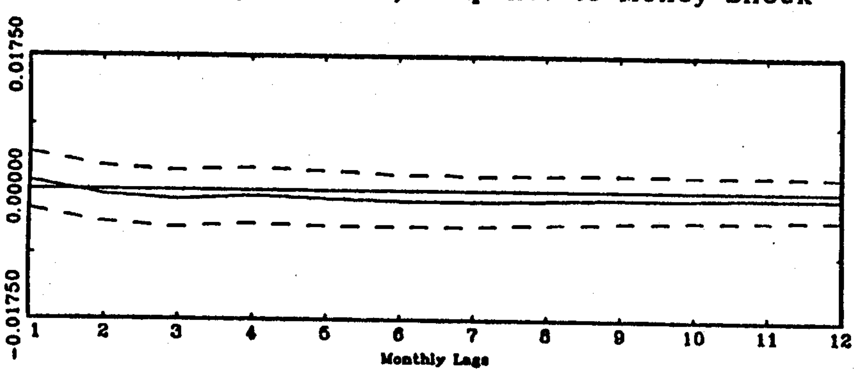


Figure 29c: (Pc−Pus−e) Response to Velocity Shock
(bias adjusted)

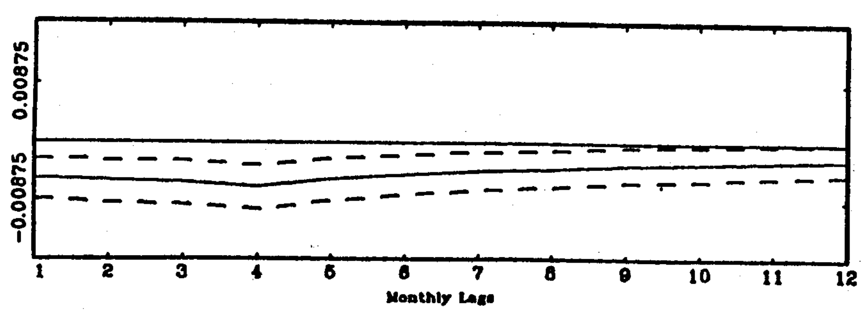


Figure 29d: (Pc−Pus−e) Response to U.S. Transitory Shock
(bias adjusted)

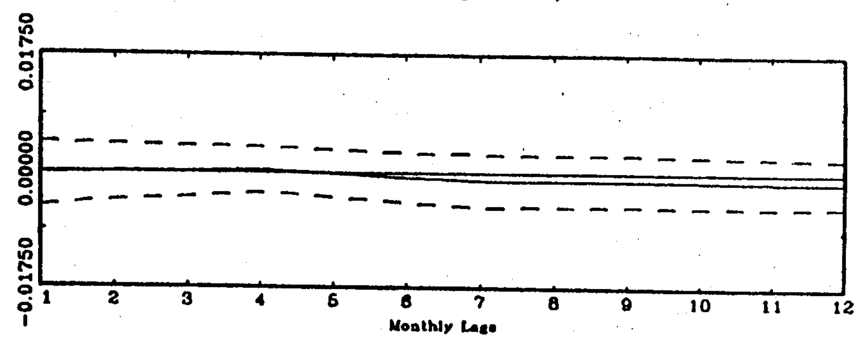


Figure 29e: (Pc−Pus−e) Response to Cdn. Transitory Shock
(bias adjusted)

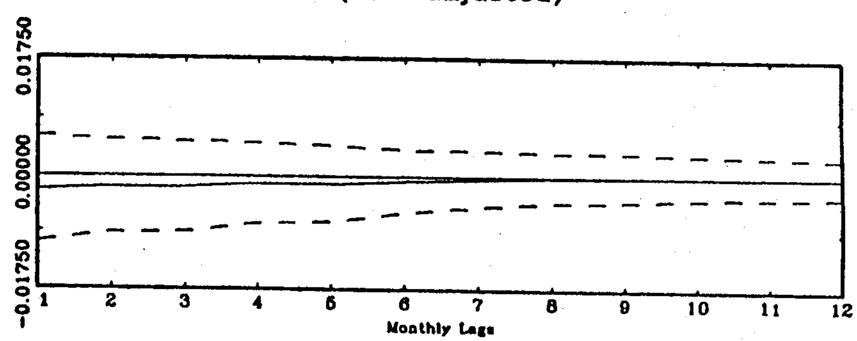


Figure 2.10a: Yc Historical Decomposition (Supply)

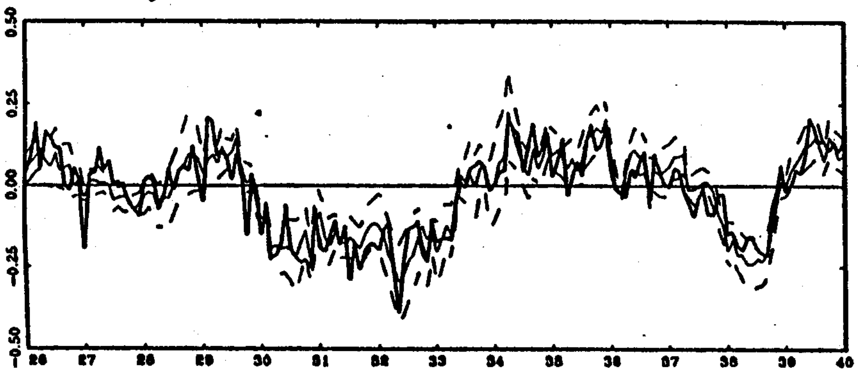


Figure 2.10b: Yc Historical Decomposition (Money)

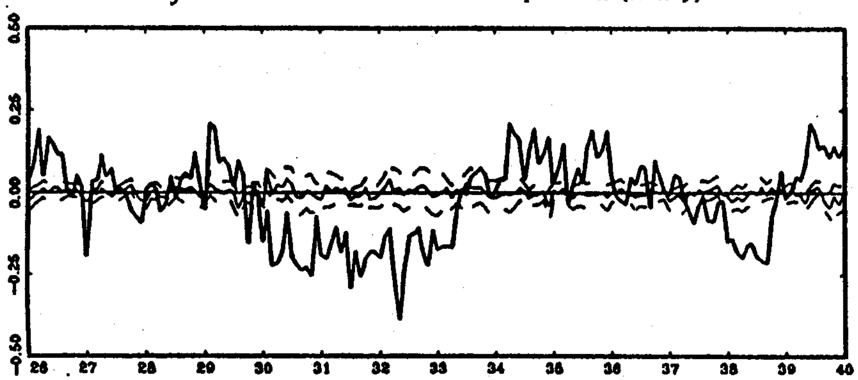


Figure 2.10c: Yc Historical Decomposition (Velocity)

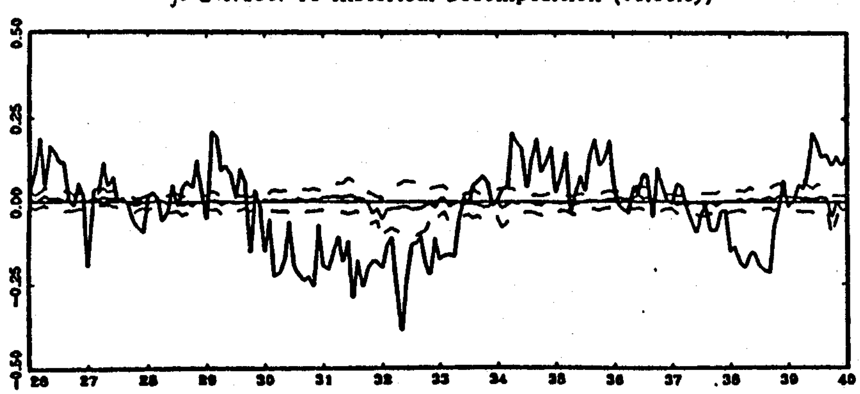


Figure 2.11a: Yus Historical Decomposition (Supply)

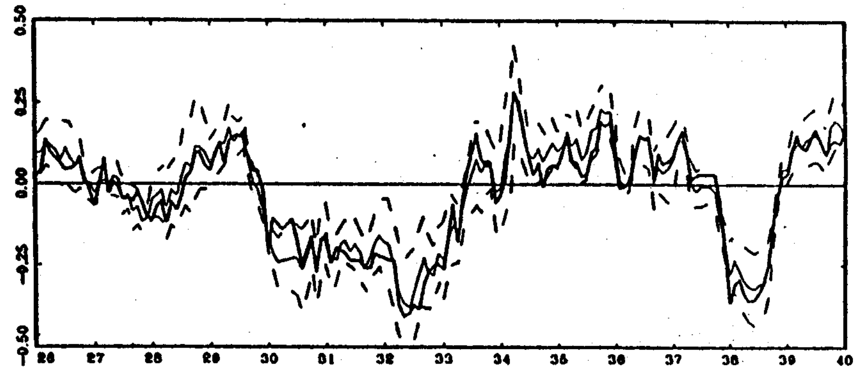


Figure 2.11b: Yus Historical Decomposition (Money)

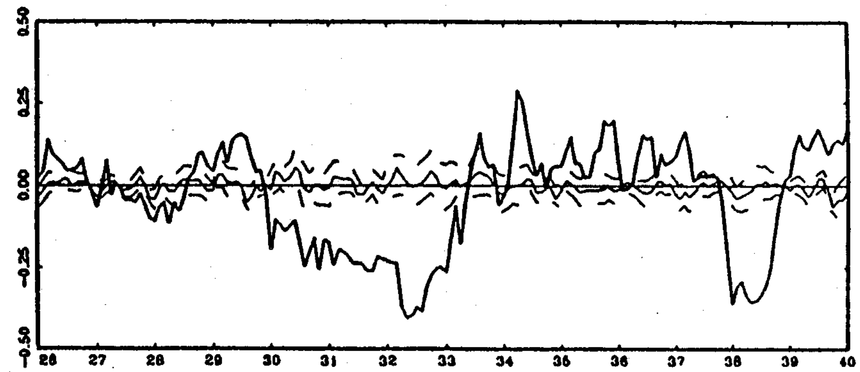


Figure 2.11c: Yus Historical Decomposition (Velocity)

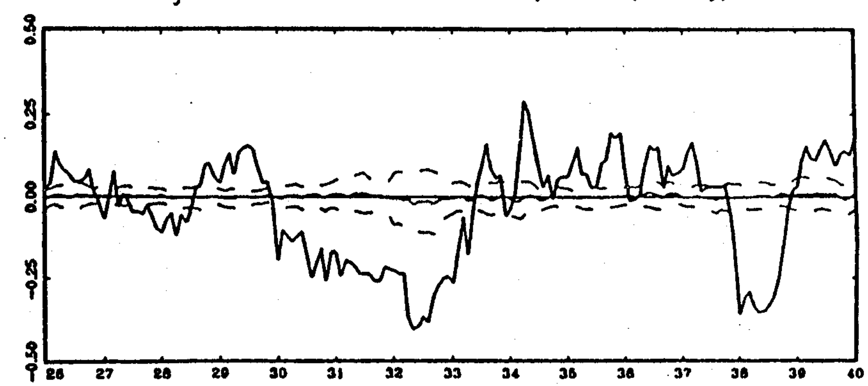


Figure 2.10d: Yc Historical Decomposition (US Transitory)

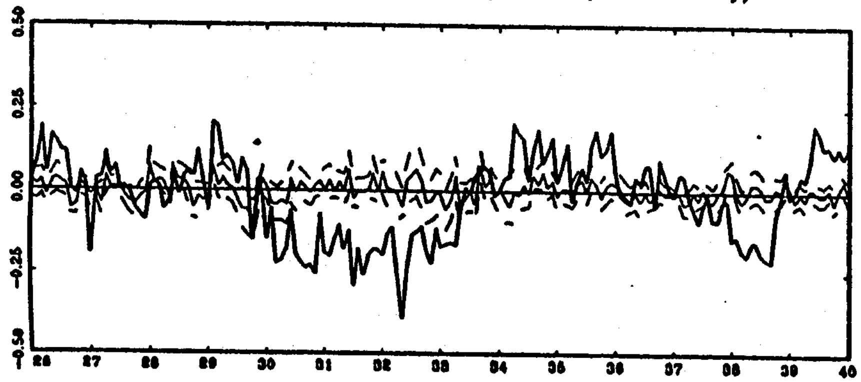


Figure 2.11d: Yus Historical Decomposition (US Transitory)

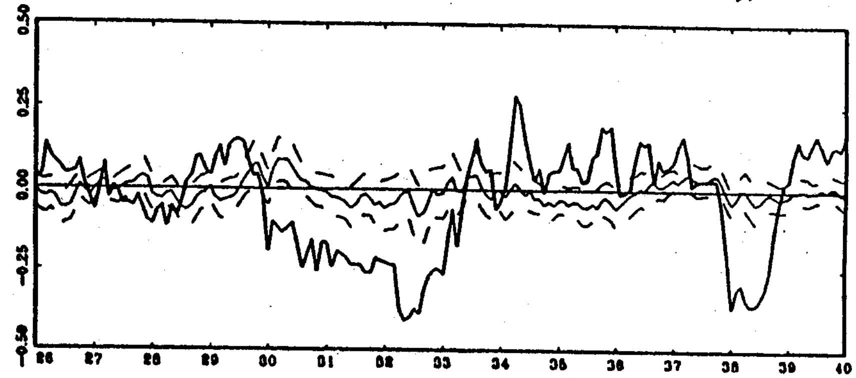


Figure 2.10e: Yc Historical Decomposition (Cdn Transitory)

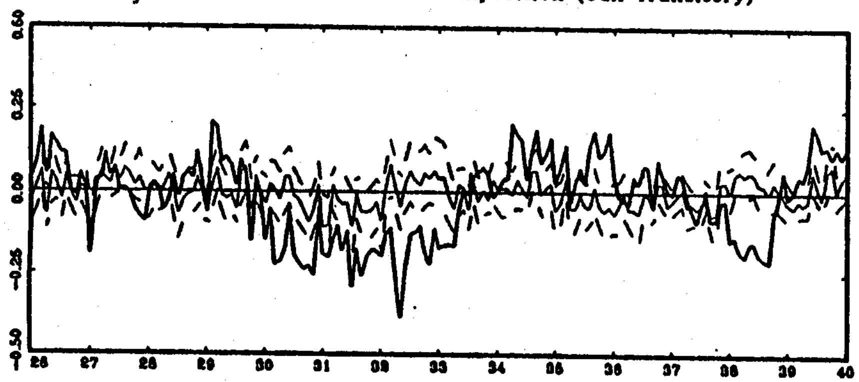


Figure 2.11e: Yus Historical Decomposition (Cdn Transitory)

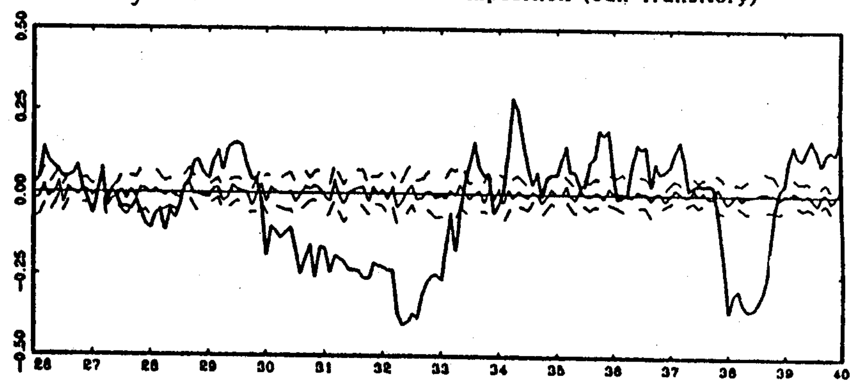


Figure 2.12a: Mc Historical Decomposition (Supply)

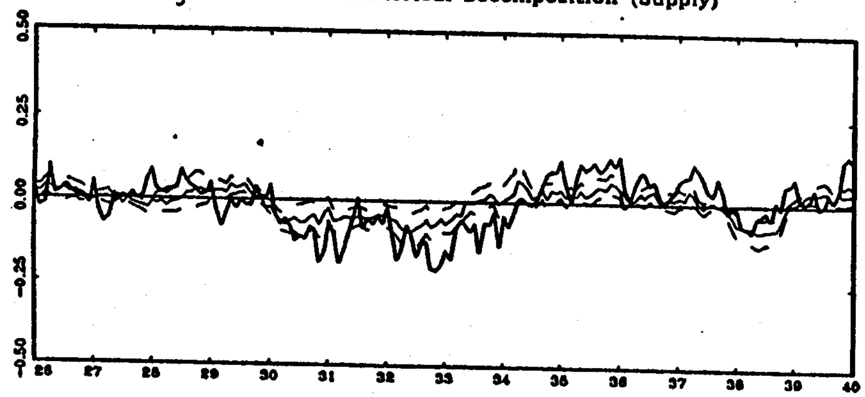


Figure 2.12b: Mc Historical Decomposition (Money)

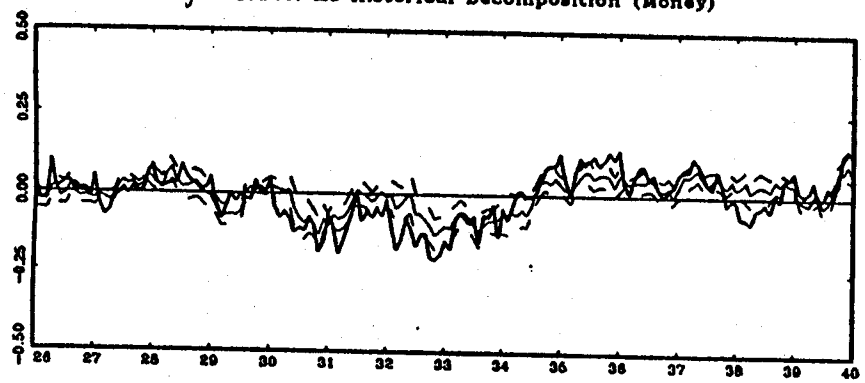


Figure 2.12c: Mc Historical Decomposition (Velocity)

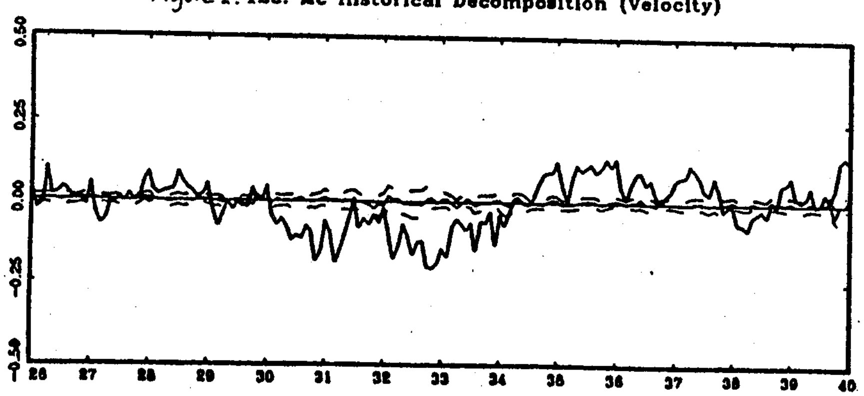


Figure 2.13a: Mus Historical Decomposition (Supply)

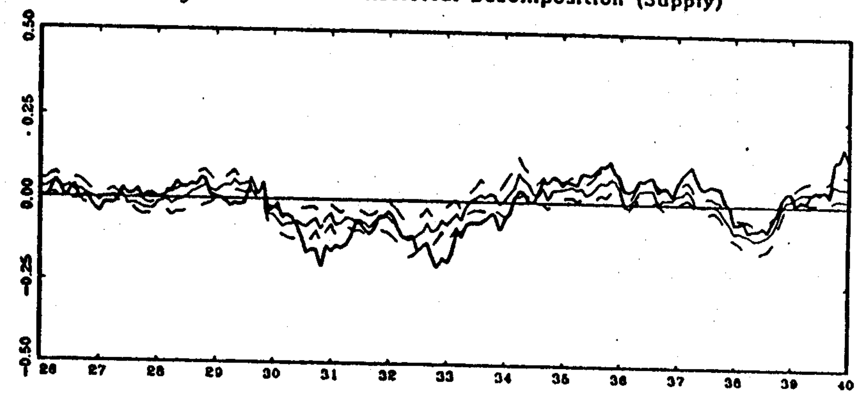


Figure 2.13b: Mus Historical Decomposition (Money)

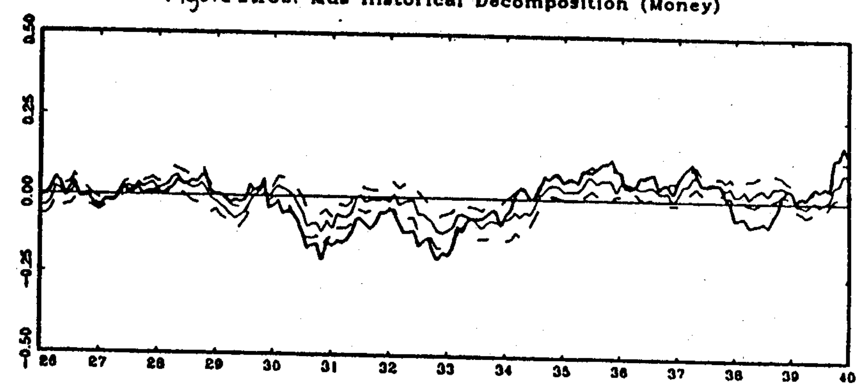


Figure 2.13c: Mus Historical Decomposition (Velocity)

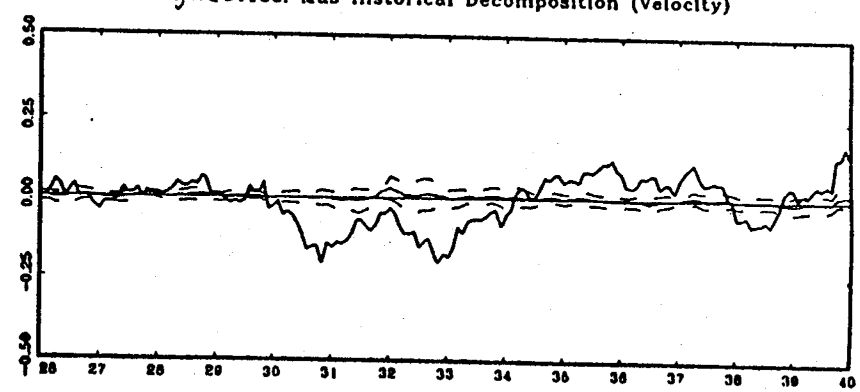


Figure 2.12d: Mc Historical Decomposition (US Transitory)

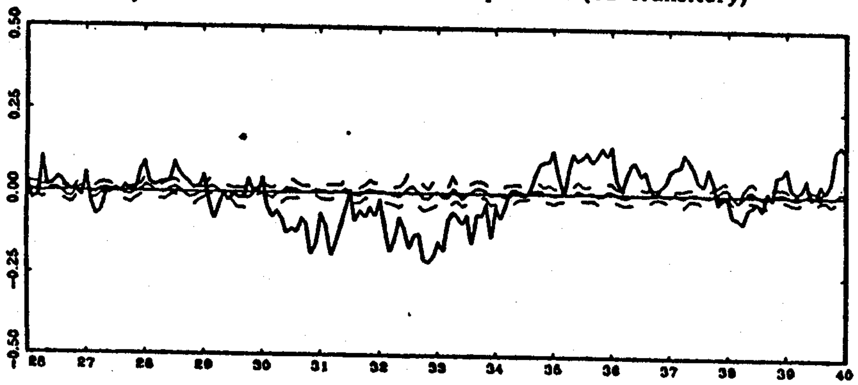


Figure 2.13d: Mus Historical Decomposition (US Transitory)

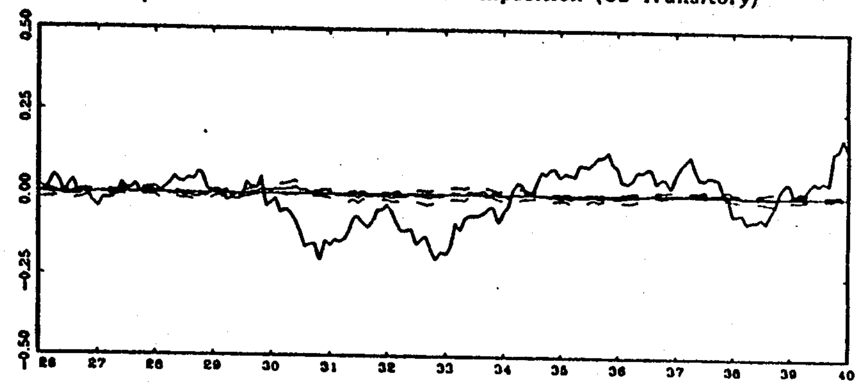


Figure 2.12e: Mc Historical Decomposition (Cdn. Transitory)

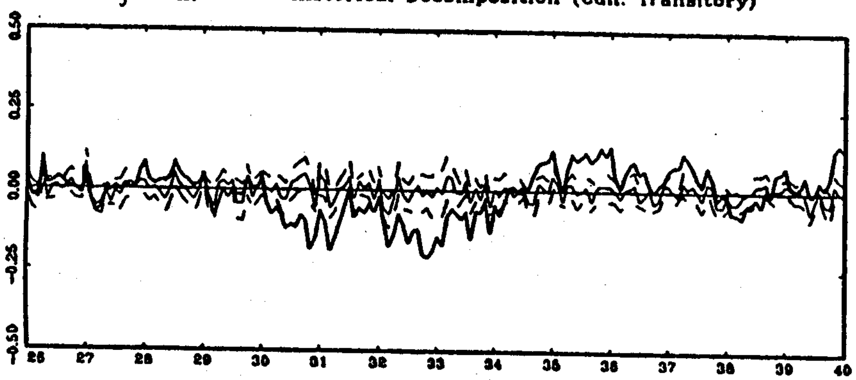
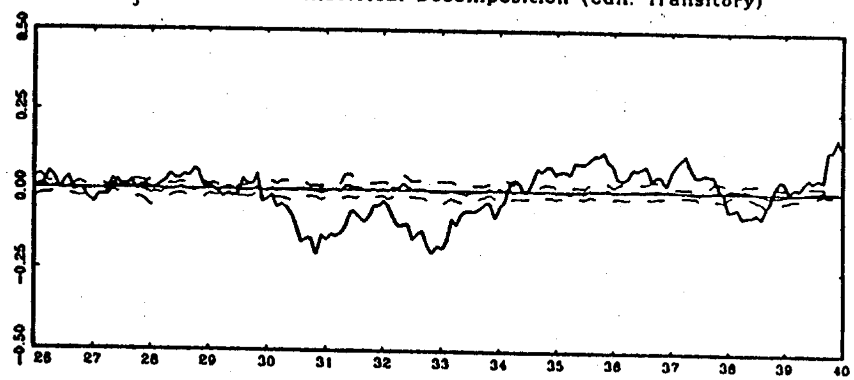


Figure 2.13e: Mus Historical Decomposition (Cdn. Transitory)



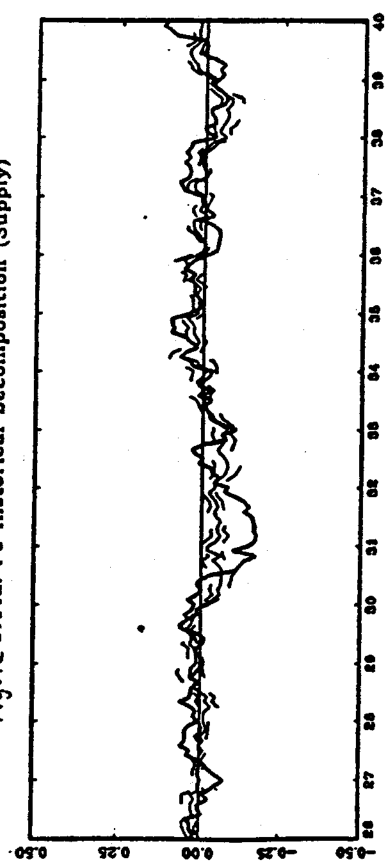


Figure 2.14a: Pc Historical Decomposition (Supply)

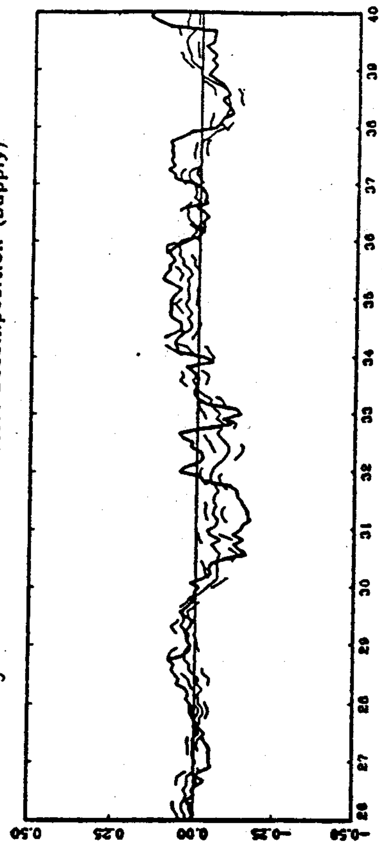


Figure 2.15a: Pus Historical Decomposition (Supply)

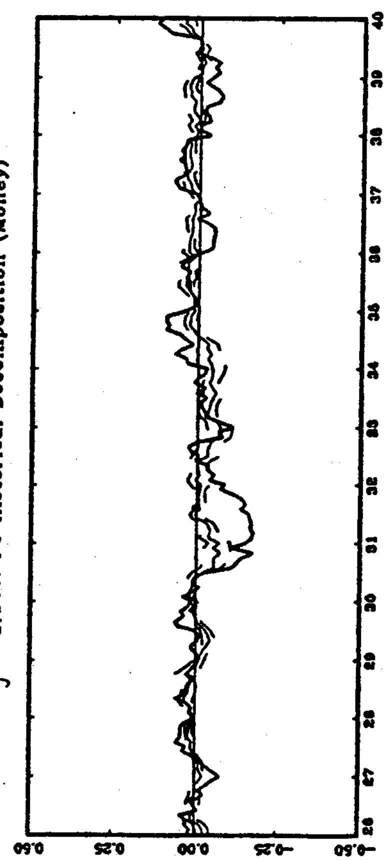


Figure 2.14b: Pc Historical Decomposition (Money)

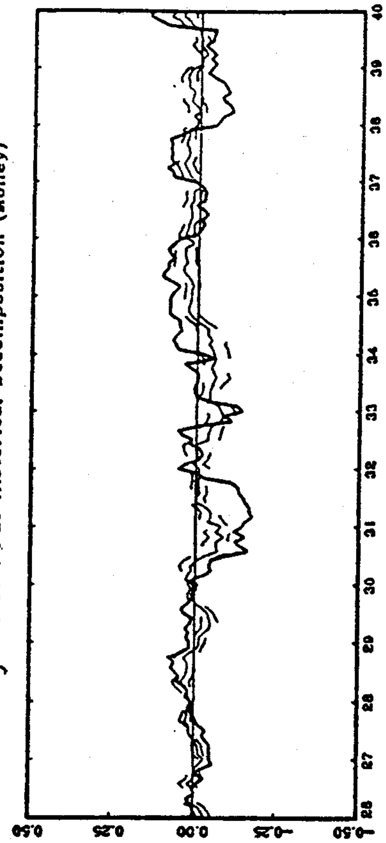


Figure 2.15b: Pus Historical Decomposition (Money)

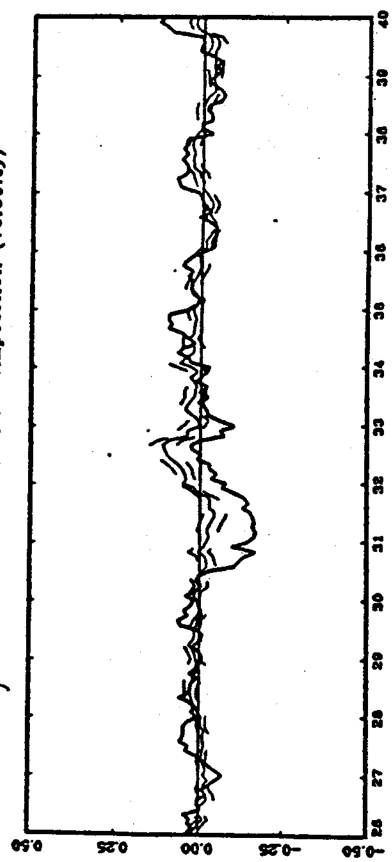


Figure 2.14c: Pc Historical Decomposition (Velocity)

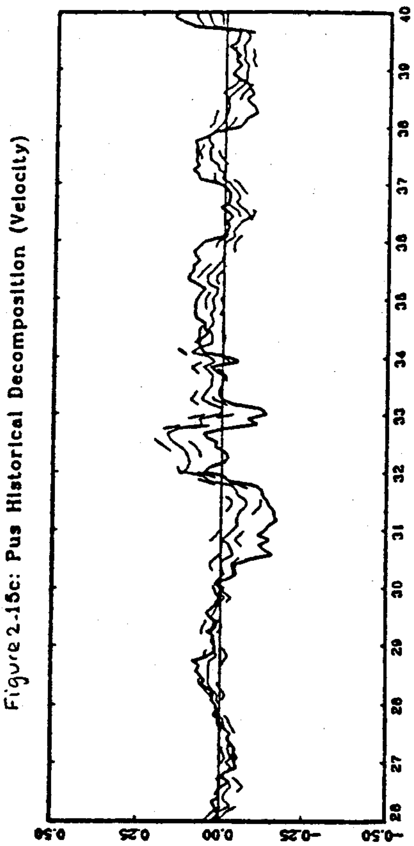


Figure 2.15c: Pus Historical Decomposition (Velocity)

Figure 2.14d: Pc Historical Decomposition (US Transitory)

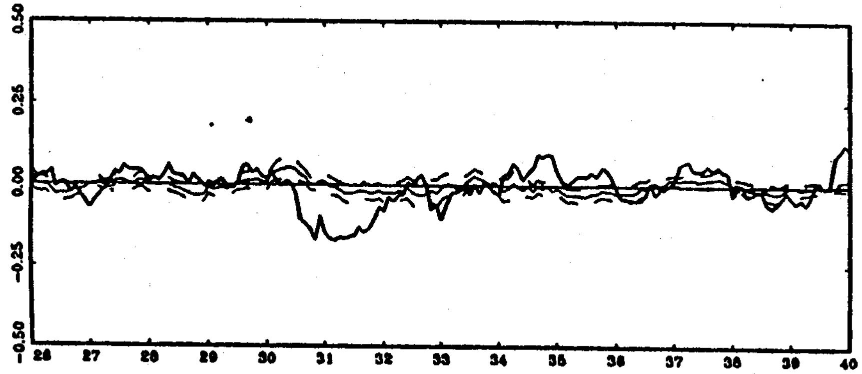


Figure 2.16d: Pus Historical Decomposition (US Transitory)

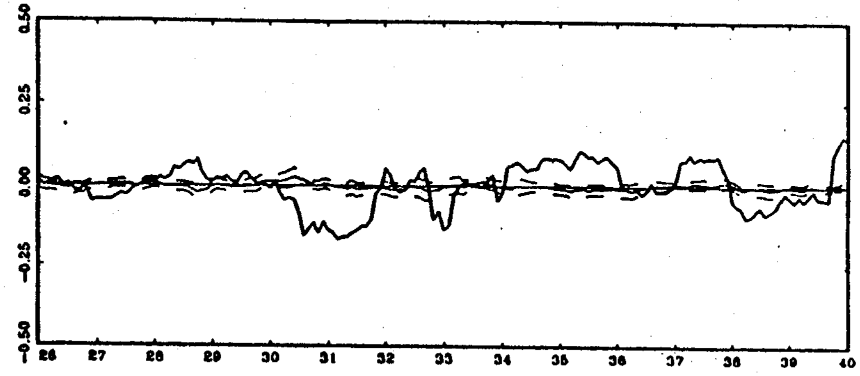


Figure 2.14e: Pc Historical Decomposition (Cdn. Transitory)

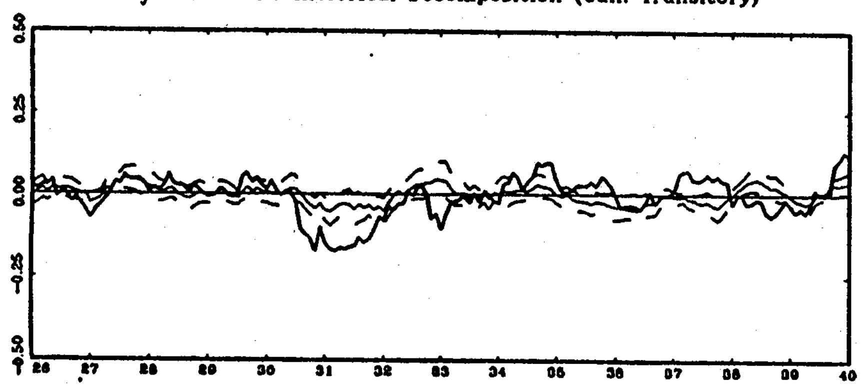


Figure 2.15e: Pus Historical Decomposition (Cdn. Transitory)

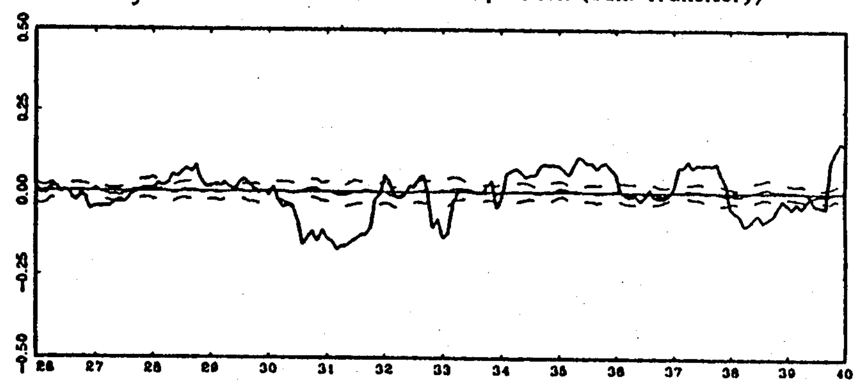


Figure 2.16a: Yc Permanent Component

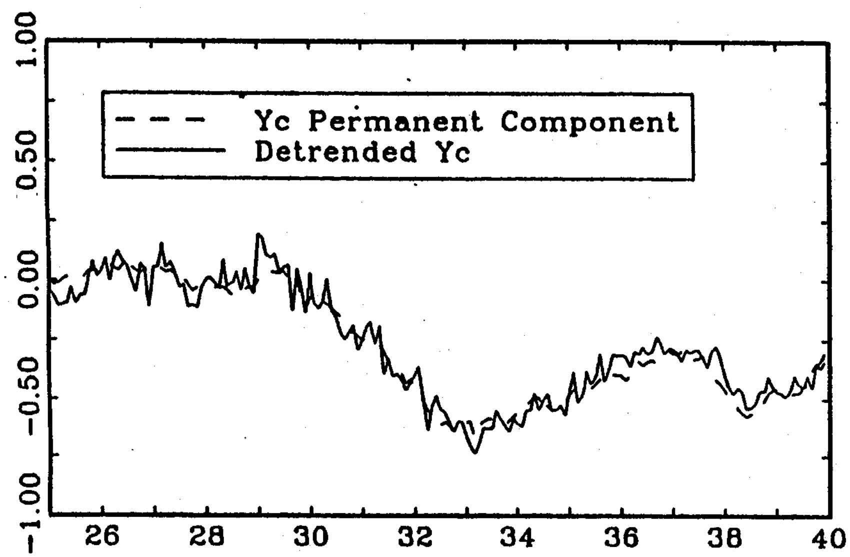


Figure 2.17a: Yus Permanent Component

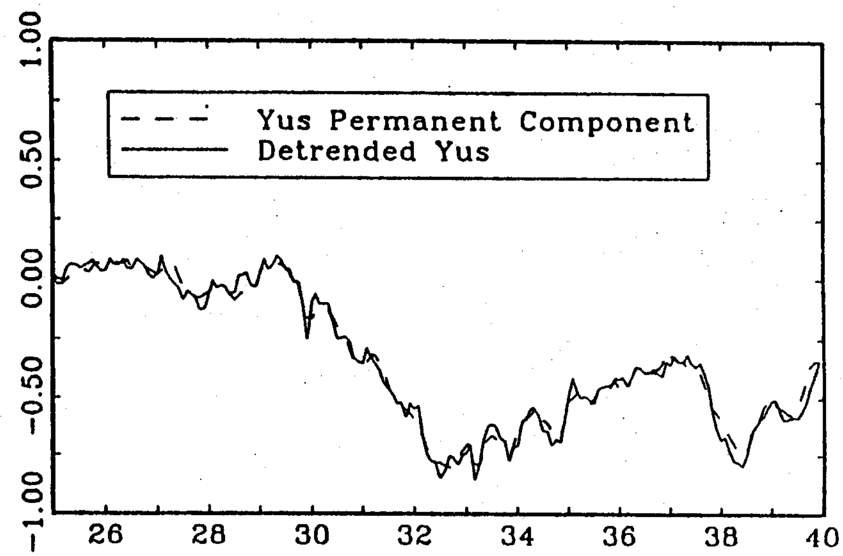


Figure 2.16b: Yc Total Transitory Component

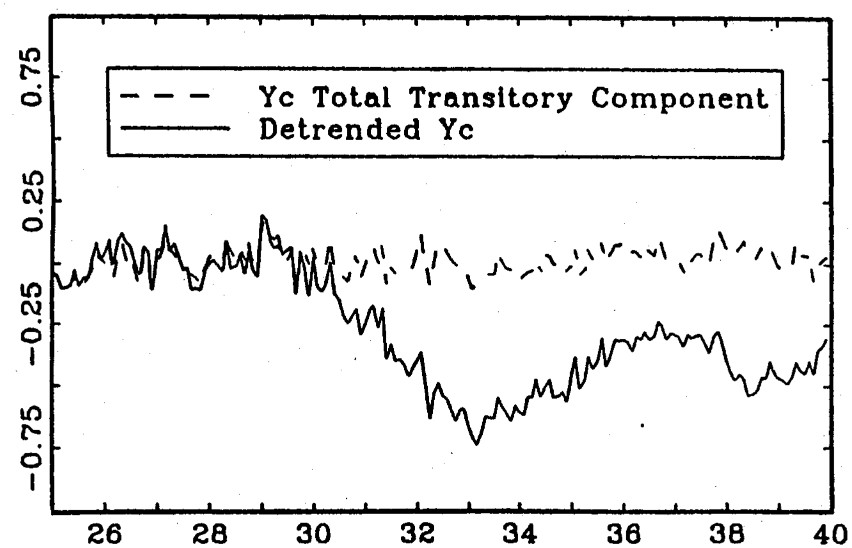
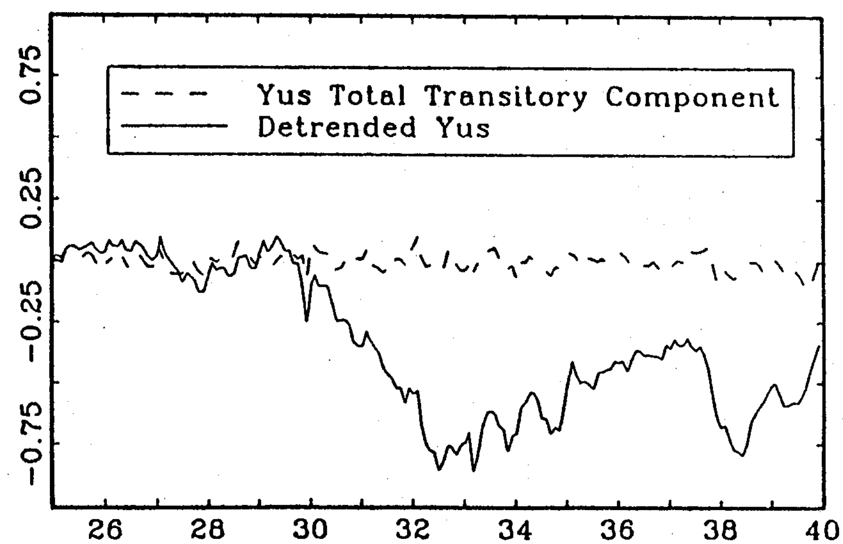


Figure 2.17b : Yus Total Transitory Component



3 CHAPTER 3: Money, Banking And The Determination Of Real And Nominal Exchange Rates

3.1 Introduction

A substantial body of evidence indicates that national price indices and foreign exchange rates display large - and permanent - departures from purchasing power parity. Moreover, a striking empirical regularity is that, under regimes where exchange rates are flexible, movements in real exchange rates largely mirror movements in nominal exchange rates, with the magnitude of movements in both dwarfing changes in relative price levels. In addition, recent empirical evidence suggests that monetary disturbances are an important source of real exchange rate fluctuations, and it is also well established that the volatility of the real exchange rate is substantially less under fixed than under flexible exchange rate regimes despite the fact that 'fundamentals' have been approximately equally volatile under the two regimes in the last thirty years. And finally, another manifestation of observed deviations from purchasing power parity is that there are sizable cross-country differences in real interest rates.[1]

This paper produces a theoretical model that is consistent with these observations, and in which the importance of monetary factors is brought into the foreground. Permanent violations of purchasing power parity are made possible by the presence of non-traded goods. Spatial separation (within and across countries) and stochastic shocks to agents' desired portfolios give rise to an important allocative role for both money and banks.[2] Within this context I consider the determination of real and nominal exchange rates and, by implication, national price levels under regimes of flexible and fixed exchange rates, as well as under regimes that differ with respect to the presence or absence of reserve requirements and exchange controls. All prices in the model are fully flexible, there is continuous market clearing, and all agents have equal access to all asset markets at each

[1] Isard (1977), Roll (1979), Frenkel (1981) and Huizinga (1987) document the existence of large and persistent violations of purchasing power parity. Betts (1993) finds that these violations occur at all horizons. Indeed, Isard (1977) and Lapham (1992) suggest that the law of one price is violated, both within and across countries, which is consistent with the theoretical formulation in the sequal.

Betts (1993) documents that a large fraction of the movement in the real exchange rate is accounted for by nominal exchange rate movements. Clarida and Gali (1994) find that shocks to both the supply of and demand for money explain a substantial amount of the variance of the real exchange rates, and Rogers (1993) reports that about one half of the forecast error variance of real exchange rates can be accounted for by monetary disturbances at short forecast horizons.

That real exchange rates are more volatile under flexible than under fixed exchange rate regimes is shown by Mussa (1986). This is true despite the fact that - since 1960 - 'fundamentals' have been approximately equally volatile under the two regimes (Flood and Rose (1993)). Finally, Isard (1983), Cumby and Obstfeld (1984), and Mark (1985) document the existence of sizable cross- country differences in real interest rates. These are related to violations of purchasing power parity by Isard (1983), Dornbusch (1983), Stulz (1987) and Devereux (1988).

[2] The potential importance of spatial separation of agents in accounting for the observations described above was suggested by Backus and Smith (1992).

date.

In this context, I consider the equilibrium consequences of changes in both monetary and real factors. Under flexible exchange rates, an increase in the money growth rate of any country causes both a real and nominal depreciation of that country's currency. Moreover, the initial magnitudes of these real and nominal exchange rate movements are equal in size, at least in equilibria where exchange rates and prices are determined only by fundamentals. In such equilibria, national price levels then rise at the relevant rate of money growth, while the real exchange rate remains constant. Thus permanent effects on the nominal and real exchange rate occur as a result of a permanent change in the rate of money growth. It bears emphasis that variations in the rate of money growth have large impacts on the nominal exchange rate compared with their impacts on relative price levels. This is true despite the full flexibility of prices.

When exchange rates are fixed, independent variations in national money growth rates are not possible. Indeed, in steady state equilibria, money growth rates across countries must be kept equal in order to maintain the fixed nominal exchange rate. Under such a regime, increases in the common rate of money growth have ambiguous effects on real exchange rates. However, it is possible to show that - in a particular sense - the effect on the real exchange rate will be smaller than would be the case under a regime of flexible rates.

For changes in real factors, which here means exogenous relative income levels, matters are substantially different. Changes in relative income levels induce the same effects on real exchange rates whether nominal exchange rates are fixed or flexible. And, when nominal rates are flexible, changes in relative income levels induce equal proportional changes in initial relative prices and, as a consequence, have no impact on the initial nominal exchange rate.

I also examine, under flexible or fixed exchange rates, the consequences of the imposition of reserve requirements or exchange controls. The imposition (or tightening) of exchange controls causes a real (and, under flexible rates, nominal) appreciation of the currency of the country imposing the controls. Reserve requirements can also be used to manipulate exchange rates, but - in a sense I describe - these are less effective devices than exchange controls for accomplishing this objective. In addition, both reserve requirements and foreign currency controls affect the ability of national monetary policy to manipulate real and nominal exchange rates.

The statements just made apply to equilibria where all variables are determined by fundamentals. Notably, the steady state 'fundamental' equilibrium is unique under both fixed and flexible exchange rates and, for identical money growth rates, is invariant to the choice of these two regimes. In addition, the fundamental equilibrium which obtains under fixed exchange rates has an interesting property: the choice of fixed nominal exchange rate value has no allocative consequences, and no effect on the real exchange rate at any date. This suggests that many discussions concerning the alignment of fixed exchange rates - for example, within the EMS - are misguided. Here such alignments are irrelevant for allocations, and they cannot aid in the attainment of a situation of (near) purchasing power parity.

Finally, I also consider the scope for multiplicity of equilibria under flexible exchange rate regimes. This is an important topic which has been considered elsewhere by Kareken and Wallace (1981), Manuelli and Peck (1990), King, Wallace and Weber (1992) and Barnett (1992). The first three of these papers show that the nominal exchange rate is indeterminate when there is sufficient substitutability between different currencies. The fourth shows that the real exchange rate can also be indeterminate when not all agents can participate in all asset markets. I show, on the other hand, that *both* the real and the nominal exchange rate are necessarily indeterminate under a regime of flexible exchange rates, despite the fact that all agents view all currencies as imperfect substitutes, and despite the fact that all agents have equal access to all asset markets. Indeed, the model possesses a continuum of non-stationary, perfect foresight equilibria that are indexed by the initial value of the real (or equivalently, as it turns out, the nominal) exchange rate. Here, all such equilibria are 'non-fundamental', and they have the property that countries whose real exchange rate is rising (falling) over time have inflation rates that are permanently below (above) their rate of money growth. In addition, in such equilibria, countries whose real exchange rate is rising (falling) over time will (under a weak restriction on parameters) have their nominal exchange rate rise at a rate exceeding (below) their relative rate of money growth. This gives an additional sense in which the effects of monetary factors can be magnified in terms of their implications for exchange rate movements. Finally, non-stationary equilibria have the property that cross-country differences in real interest rates will exist at all dates, although these will tend to disappear asymptotically.

The vehicle I use for considering these issues is a two-country, single good[3] pure exchange overlapping generations model. In each country there is a government that issues both fiat currency and interest-bearing debt. While international trade in goods is limited, allowing permanent deviations from purchasing power parity to be observed, international trade in all assets is unrestricted. All agents have identical access to all asset markets, all goods and asset markets are perfectly competitive and all markets clear at each date.

Within each country there are two spatially distinct locations. Agents move between loctaions

[3]This good is not traded across countries. It is conceptually straightforward to have more than one good in the model and to have some traded and others non-traded goods. However, such a formulation adds complexity without changing the substantive issues under consideration.

in a stochastic manner, both domestically and internationally. Only currency is transportable between locations, and inter- location exchange requires the currency of the country in which the seller is located. As a result, agents seek to diversify their portfolios, holding the currencies of both countries as well as interest-bearing assets that dominate money in rate of return.[4] Agents' demands for these assets, and their supply as determined by national monetary policies, are then fundamentals for the real (and nominal) exchange rate.

The possibility of stochastic relocation, coupled with the role of currency in inter-location exchange, plays the role of a 'liquidity preference shock' in the Diamond-Dybvig (1983) model. Banks, therefore, arise to insure agents against their random, currency-specific liquidity needs. In order to provide this insurance, banks in each country hold reserves of both the foreign and domestic currency, and in addition they invest in interest-bearing government bonds. The optimal portfolio weights for these banks impinge on real exchange rate determination in a manner that reflects how the liquidity preference shocks generate aggregate demands for the currencies of each country.

Although the model is one with two-period lived overlapping generations, the fact that inter-location exchange must be accomplished using the seller's currency causes it to resemble a hybrid cash-in-advance, overlapping generations model. In addition, the existence of spatial separation renders significance to the timing of transactions; in this sense the model resembles the liquidity effects models of Grilli and Roubini (1992,1993) and Schlagenhauf and Wrase (1992a).

The remainder of this paper is organized as follows. Section 3.2 describes the economic environment, while Section 3.3 outlines the nature of trade and the role for banks. Sections 3.4 and 3.5 consider the properties of a full general equilibrium under flexible exchange rates, and Section 3.6 examines the issue of multiple equilibria under this policy regime. Section 3.7 considers fixed exchange rate regimes, while Section 3.8 analyzes the consequences of reserve requirements and foreign currency controls. Section 3.9 concludes.

3.2 The Environment

I consider a two-country, single good, pure exchange model. Within each country there are two locations; at the beginning of a period agents in each country are assigned to one of these, and within a country locations are symmetric.

Each country is populated by an infinite sequence of two-period lived, overlapping generations. Time, then, is obviously discrete, and is indexed by t=1,2.... Within each location at each date there is a continuum of (ex ante) identical young agents with unit mass. Also, all residents of a

[4]This formulation resembles that in Champ, Smith and Williamson (1992), which has many of these features in a single country context.

given country are identical ex ante, although I allow for heterogeneity of agents across countries.

Each agent in the domestic (foreign) country is endowed with y^d (y^f) units of the single, perishable commodity, and for simplicity I assume that agents have a zero endowment when old. I also assume, again for simplicity, that all agents care only about old age consumption, which is denoted simply by c, and that agents have the utility function u(c)=ln c, which is common across countries.[5]

I assume that goods are immobile between countries or locations; that is, transportation costs for the good are prohibitive. Agents, however, do move between locations - either domestically or internationally - in a manner I now describe.

At the beginning of a period, young agents are assigned to a specific location in either the domestic or foreign country. These agents have a positive probability of being relocated before the end of the period; relocations can occur either within a country or across countries. Let π_d^d (π_f^f) be the probability that a resident of the domestic (foreign) country is relocated within his own country, and π_f^d (π_d^f) be the probability that a resident of the domestic (foreign) country is relocated to the foreign (domestic) country. The probability of relocation is constant across periods, known by all agents, and is iid across agents in a given country. Thus there is no aggregate randomness, and net domestic relocations are always zero. This need not be the case for relocations of agents across countries. Finally, to keep the locations within a country symmetric, I adopt the convention that if residents of location 1 (2) of either country are relocated internationally, they are relocated to location 1 (2) of the other country.

Since goods are not transported between locations, agents who are relocated must carry with them some assets. I allow for two types of primary assets; each country issues its own fiat currency and its own interest-bearing bonds. Let M_t^d (M_t^f) be the per capita money supply of the domestic (foreign) country at t, and let B_t^d (B_t^f) be the nominal outstanding per capita quantity of domestically (foreign) issued bonds at t. The liabilities of the domestic (foreign) government are each denominated in units of its own currency. Let p_t^d (p_t^f) denote the domestic (foreign) price level at t, and e_t denote the domestic currency price of one unit of foreign currency, so that e is the nominal exchange rate. Thus, $x_t \equiv e_t p_t^f / p_t^d$ is the real exchange rate of the domestic country, and let $m_t^d \equiv M_t^d / p_t^d$ and $b_t^d \equiv B_t^d / p_t^d$ ($m_t^f \equiv M_t^f / p_t^f$ and $b_t^f \equiv B_t^f / p_t^f$) denote the supplies of real balances and real bonds by the domestic (foreign) government at t.

[5]All of these assumptions can be relaxed at the expense of considerable added complexity. In particular, I can allow for multiple goods, some of which are traded internationally, and can allow agents to make a non-trivial consumption-savings decision when young. These additions substantially complicate the analysis, without substantively affecting the issues of interest here.

I assume that currency is transportable between locations (and that it is not counterfeitable) whereas the same is not true of bonds or other, privately issued liabilities. In addition, a country's own currency is used for inter-location exchange within that country, whereas the foreign country currency is used for inter-location exchange between countries. This amounts to imposing a cash-in-advance constraint on all inter-location exchange; a buyer in these kinds of transactions must pay for purchases using the currency of the seller. This convention is an extension to a multi-country context of the formulation used in Champ, Smith and Williamson (1992). [6]

I assume that bonds issued by the domestic (foreign) government at t pay the gross nominal rate of interest I_t^d (I_t^f) between t and t+1. Thus $R_{dt}^d = I_t^d p_t^d / p_{t+1}^d$ and $R_{ft}^f = I_t^f p_t^f / p_{t+1}^f$ are the gross real rates of interest received by the holders of these instruments within the relevant country. Clearly, when both I_t^d and I_t^f >1 so that currency is dominated in rate of return the assumptions of the preceding paragraph imply that all agents will, ex ante, wish to hold diversified portfolios comprising both types of currency and bonds.

The fact that currency is required for inter-location exchange means that the possibility of stochastic relocation plays the role of a liquidity preference shock in the Diamond-Dybvig (1983) model. Agents who are relocated within (across) countries will wish to liquidate other asset holdings and use the proceeds to acquire the currency of the relevant country. It is natural for banks to arise in order to insure agents against the associated risks of premature asset liquidation. Doing so will involve them holding reserves of both currencies, as well as bonds. The behaviour of these banks is described in the next section.

3.3 Trading, And The Role Of Banks

3.3.1 The Timing Of Trade

Since agents do not consume when young, all trade takes the following form. At the beginning of period t in each location there are some old agents who have arrived there from elsewhere. These agents are carrying the currency of the location they arrive in, since currency is the only asset that can be transported between locations. This currency is then used to buy goods from young agents. In addition, there are old agents in each location who have remained there from the previous

[6] By inter-location exchange I refer, of course, to situations where a buyer who has beeen relocated purchases goods in the new location. The assumption that only currency is useful in inter-location exchange also appears in Townsend (1987), Mitsui and Watanabe (1989) and Hornstein and Krusell (1993). This assumption can be motivated - as in Townsend (1987) - by appealing to limitations on the degree of communication between locations. See Champ, Smith and Williamson (1992) for a further discussion of this issue. The notion that government bonds are not useful in inter-location exchange could also be motivated by the possibility - which is common in most countries - that they are issued in denominations too large to be useful in transactions.

period; these agents consume the income generated by any assets that they hold - either directly or indirectly - and they do not require currency in order to do so.

An essential ingredient in any model with spatial separation and inter-location mobility is the timing of transactions. My timing assumptions are as follows. At the beginning of period t old agents who hold bonds - either directly or indirectly - are paid in units of goods in the relevant location, which they consume. Old agents who hold currency use it to purchase goods from young agents; goods purchases by assumption occur in the seller's currency.

Once goods trade is completed, asset trading begins. Young agents can either hold assets directly, or they can make a bank deposit and holds assets indirectly. After asset trading is completed at t, young agents find out whether or not they are to be relocated, and their ultimate destination. If young agents are to be relocated, only the currency of the country of their destination is of use to them; any other assets that they hold directly become valueless to them.[7] If young agents hold bank deposits, then they go to their banks, and make a withdrawal in the relevant currency before being relocated. This timing of transactions is depicted in Figure 3.1.

The risk of relocation implies that agents will not wish to hold primary assets directly. Rather, they will prefer to have their savings intermediated by banks which take their deposits, hold the primary assets in the model directly, and promise state contingent payments to depositors depending on their relocation status and ultimate destination. I now turn to a description of these banks.

3.3.2 Bank Behaviour

I assume that, in each location, there are some banks that behave competitively in the sense that they view themselves as being unable to influence the equilibrium returns on assets. On the deposit side these intermediaries behave as Nash competitors; that is, they announce state contingent returns to depositors as a function of relocation status and ultimate destination. In addition, there is assumed to be free entry into intermediation. Thus competition among potential intermediaries for deposits means that - in a Nash equilibrium - deposit returns must be chosen to maximize the expected utility of a representative depositor, subject to bank balance sheet constraints which I now describe.

I focus throughout on the situation where nominal interest rates in each country are strictly positive at each date; that is, in which $I_t^d > 1$ and $I_t^f > 1$ hold for all t. In equilibria with this property, banks will hold (either) currency *only* in order to accomodate the liquidity needs of agents who are relocated. Any excess holdings of currency are sub-optimal, as bonds dominate money in

[7] Recall that at this point asset trading has been concluded in period t.

rate of return.

Let m_{dt}^{d} denote the per depositor holdings of domestic real balances by domestic banks at t, and let m_{dt}^{f} denote the time t quantity of foreign real balances held by domestic banks (again, per depositor). The former, of course, are measured in units of domestic goods, while the latter are measured in foreign goods. Similarly, let b_{dt}^{d} (b_{dt}^{f}) denote the per depositor real holdings of domestically (foreign) issued bonds at t. The same comment about units applies. Then the value, in domestic goods, of m_{dt}^{f} units of foreign real balances at time t is given by $m_{dt}^{f}(e_t p_t^f / p_t^d) \equiv m_{dt}^{f} x_t$, and similarly, the domestic goods value of b_{dt}^{f} units of bonds denominated in foreign goods is $b_{dt}^{f} x_t$ at t. Since all savings are intermediated, a representative domestic bank will receive a real deposit of y^d per depositor at each date. Thus the bank's balance sheet constraint is

$$y^d \geq m_{dt}^{d} + b_{dt}^{d} + x_t(m_{dt}^{f} + b_{dt}^{f}); t \geq 1. \tag{1}$$

I assume that each bank offers a set of state contingent real gross returns on deposits. These are denoted as follows. r_{dt}^{d} is the return delivered to domestic depositors at t who are relocated domestically, while r_{ft}^{d} is the real return paid to domestic depositors who are relocated abroad. r_t^d is the real return paid to domestic depositors who are not relocated.[8] The returns the bank can offer are, of course, constrained by its portfolio composition and the returns on assets that it faces. These constraints are as follows.

At time t, a fraction π_d^d of the bank's depositors are relocated domestically. These agents have been promised a payment of r_{dt}^{d} per unit deposited, and each of them has deposited y^d. Thus the per depositor obligation to these individuals is $\pi_d^d r_{dt}^d y^d$. These agents must be given domestic currency to accomplish their transactions. This will be done using the bank's holdings of domestic real balances: all of these holdings will be paid out to domestically relocated depositors at t who carry them into t+1. The real return between periods on these real balances is p_t^d / p_{t+1}^d; thus the bank faces the budget constraint

$$\pi_d^d r_{dt}^d y^d \leq m_{dt}^{d}(p_t^d / p_{t+1}^d); t \geq 1. \tag{2}$$

For domestic agents who are relocated abroad (of whom there are π_f^d per depositor), the bank has promised a payment of $r_{ft}^d y^d$. These agents must be paid in foreign currency in order to make their purchases; thus payments are constrained by the bank's foreign currency holdings m_{dt}^{f}. These holdings have a domestic goods value of $m_{dt}^{f} x_t$. In addition, domestic agents who are relocated

[8]It bears emphasis that the assumptions on timing and communication between locations imply that domestic (foreign) residents make deposits only in domestic (foreign) banks.

abroad carry these real balances with them between t and t+1, earning a gross real return of $(p_t^d/p_{t+1}^d)(e_{t+1}/e_t)$.[9]. Thus

$$\pi_f^d r_{ft}^d y^d \leq m_{dt}^f x_t (p_t^d/p_{t+1}^d)(e_{t+1}/e_t); t \geq 1, \tag{3}$$

must hold.

For domestic agents who are not relocated - who comprise a fraction 1-π_d^d-π_f^d of depositors - the bank promises a total repayment of $(1 - \pi_d^d - \pi_f^d)r_t^d y^d$. This must be financed out of the bank's earnings on its bonds, since all currency holdings are liquidated to pay off agents who are relocated.[10] Foreign issued bonds held by domestic banks yield a real return - in units of domestic goods - of $I_t^f(p_t^d/p_{t+1}^d)(e_{t+1}/e_t) \equiv R_{dt}^f$.[11] The return constraint relevant to the choice of r_t^d is, in units of domestic goods,

$$(1 - \pi_d^d - \pi_f^d)r_t^d y^d \leq b_{dt}^d R_{dt}^d + b_{dt}^f x_t R_{dt}^f; t \geq 1. \tag{4}$$

Competition among banks for deposits implies that - in a Nash equilibrium - deposit return schedules and bank portfolio allocations must be chosen to maximize the expected utility of a representative depositor, subject to constraints (1)-(4). In other words, in equilibrium domestic banks must choose $r_{dt}^d, r_{ft}^d, r_t^d, m_{dt}^d, m_{dt}^f, b_{dt}^d$ and b_{dt}^f to solve the problem

(P.1) $\quad \max \pi_d^d ln(r_{dt}^d y^d) + \pi_f^d ln(r_{ft}^d y^d) + (1 - \pi_d^d - \pi_f^d) ln(r_t^d y^d)$

subject to (1) to (4) and non-negativity.

This problem can be transformed as follows. Let γ_{dt}^d (γ_{ft}^d) denote a domestic bank's ratio of domestic (foreign) currency real holdings to deposits at t; that is

$$\gamma_{dt}^d \equiv m_{dt}^d/y^d, \tag{5}$$

$$\gamma_{ft}^d \equiv m_{dt}^f x_t/y^d. \tag{6}$$

Similarly, let β_{dt}^d $(1-\gamma_{dt}^d - \gamma_{ft}^d - \beta_{dt}^d)$ denote a domestic bank's ratio of real domestically (foreign) issued bonds to deposits at t, so that

$$\beta_{dt}^d \equiv b_{dt}^d/y^d, \tag{7}$$

[9] In particular, e_t/p_t^d units of domestic goods are requires to obtain at t one unit of foreign currency (in nominal terms). At t+1, this unit of currency has a domestic goods value of e_{t+1}/p_{t+1}^d. Hence the real return, to a domestic resident, of holding foreign real balances is $(e_{t+1}/p_{t+1}^d)(p_t^d/e_t)$

[10] Recall that the bank does not wish to carry currency between periods, since money is dominated in rate of return.

[11] To see this, note that e_t/p_t^d units of domestic goods are required to buy one unit of (nominally denominated) foreign bonds at t. This bond unit repays I_t^f units of the foreign currency at t+1, which has a domestic goods value of $I_t^f(e_{t+1}/p_{t+1}^d)$ at that date. Thus the real return, to domestic residents, of holding a foreign bond is $I_t^f(e_{t+1}/p_{t+1}^d)(p_t^d/e_t)$.

$$(1-\gamma_{dt}^d-\gamma_{ft}^d-\beta_{dt}^d) \equiv b_{dt}^f x_t/y^d. \tag{8}$$

Then constraints (2) to (4) can be re-written as

$$r_{dt}^d \leq \gamma_{dt}^d(p_t^d/p_{t+1}^d)/\pi_d^d, \tag{9}$$

$$r_{ft}^d \leq \gamma_{ft}^d(p_t^d/p_{t+1}^d)(e_{t+1}/e_t)/\pi_f^d, \tag{10}$$

$$r_t^d \leq [\beta_{dt}^d R_{dt}^d+(1-\gamma_{dt}^d-\gamma_{ft}^d-\beta_{dt}^d)R_{dt}^f]/(1-\pi_d^d-\pi_f^d), \tag{11}$$

which must hold $\forall$ t $\geq$ 1.

The bank then seeks at each date to solve the problem

(P.1′) $\max \pi_d^d lnr_{dt}^d+\pi_f^d lnr_{ft}^d+(1-\pi_d^d-\pi_f^d)lnr_t^d$

subject to (9) to (11) and non-negativity. The solution to this problem sets

$$\gamma_{dt}^d = \pi_d^d,$$

$$\gamma_{ft}^d = \pi_f^d. \tag{12}$$

In addition, an absence of arbitrage opportunities in bond markets requires that $R_{dt}^d = R_{dt}^f$. This condition is equivalent to the uncovered interest parity condition

$$I_t^d = I_t^f(e_{t+1}/e_t); t \geq 1. \tag{13}$$

For future reference it will be convenient to note an alternate form of (13):

$$R_{dt}^d = R_{ft}^f(x_{t+1}/x_t); t \geq 1. \tag{13′}$$

The problem of banks located in the foreign country is completely symmetric. In order to describe it, I proceed as before and define γ_{ft}^f (γ_{dt}^f) to be the ratio of foreign (domestic) country currency to deposits in foreign banks; thus

$$\gamma_{ft}^f \equiv m_{ft}^f/y^f, \tag{14}$$

and

$$\gamma_{dt}^f \equiv m_{ft}^d/y^f x_t, \tag{15}$$

hold, where m_{ft}^f (m_{ft}^d) is the per depositor holding of foreign (domestic) country real balances by a representative foreign bank at t. Similarly, β_{ft}^f $(1-\gamma_{ft}^f-\gamma_{dt}^f-\beta_{ft}^f)$ is the ratio of foreign (domestic) real bond holdings to deposits of a foreign bank. Then we have

$$\beta^f_{ft} \equiv b^f_{ft}/y^f, \tag{16}$$

$$(1-\gamma^f_{ft}-\gamma^f_{dt}-\beta^f_{ft}) \equiv b^d_{ft}/y^f x_t, \tag{17}$$

where b^f_{ft} (b^d_{ft}) is the (per-depositor) holding of foreign (domestic) real bonds by a foreign bank at date t.

The budget constraints facing a foreign bank are as follows:

$$r^f_{ft} \leq \gamma^f_{ft}(p^f_t/p^f_{t+1})/\pi^f_f; t \geq 1, \tag{18}$$

$$r^f_{dt} \leq \gamma^f_{dt}(p^f_t/p^f_{t+1})(e_t/e_{t+1})/\pi^f_d; t \geq 1, \tag{19}$$

$$r^f_t \leq [\beta^f_{ft}R^f_{ft}+(1-\gamma^f_{ft}-\gamma^f_{dt}-\beta^f_{ft})R^d_{ft}]/(1-\pi^f_f-\pi^f_d); t \geq 1, \tag{20}$$

where r^f_{ft} (r^f_{dt}) is the gross real return on deposits promised to foreign agents who are relocated within (across) countries, r^f_t is the return promised to foreign agents who are not relocated, and R^d_{ft} is the gross real return to foreign holders of domestically issued bonds. $R^d_{ft} \equiv I^f_t(p^f_t/p^f_{t+1})(e_t/e_{t+1})$ holds.[12]

Competition among foreign banks for depositors then forces these banks - in equilibrium - to choose return schedules and portfolio weights solving the problem

$$\text{(P.2)} \quad \max\ \pi^f_f lnr^f_{ft} + \pi^f_d lnr^f_{dt} + (1-\pi^f_f-\pi^f_d)lnr^f_t$$

subject to (18) to (20) and non-negativity. The solution to this problem sets

$$\gamma^f_{ft} = \pi^f_f,$$

$$\gamma^f_{dt} = \pi^f_d. \tag{21}$$

In addition, equation (13) or (13′) must hold in order for agents to perceive no arbitrage opportunities in bond markets.

3.4 General Equilibrium: Flexible Exchange Rates

I now describe the determination of a full general equilibrium of the model under a regime of flexible exchange rates. Central to this determination is a complete description of the behaviour of the government of each country, which I now provide.

[12] In particular, $1/e_t p^f_t$ units of the foreign good are required to purchase one (nominal) unit of domestically issued bonds at t. These bonds return I^d_t units of domestic country currency at t+1. This currency has a foreign goods value of $1/e_{t+1}p^f_{t+1}$ per unit at t+1. Hence the gross real return to foreign residents of holding domestic country bonds from t to t+1 is $I^d_t(p^f_t/p^f_{t+1})(e_t/e_{t+1})$. The same reasoning yields the real return on foreign holdings of domestic currency in equation (19), except that currency bears no interest.

3.4.1 Government Activity

At each date t$\geq$1, the domestic (foreign) government has an outstanding money stock (per capita) of M_t^d (M_t^f) held by private agents, and a quantity of nominal, interest-bearing bonds outstanding of B_t^d (B_t^f) per capita. In addition, the domestic (foreign) government holds reserves of the foreign (domestic) currency in the amount of Z_{dt}^f (Z_{ft}^d) per capita at t. I assume (in this section) that neither government levies taxes nor has direct expenditures. Thus, at each date, the government of each country must generate enough seignorage revenue to service its debt, and to finance any changes in its net reserve position. In other words, the domestic country government faces the following budget constraint for t$\geq$1:

$$I_{t-1}^d B_{t-1}^d = M_t^d - M_{t-1}^d + B_t^d - e_t(Z_{dt}^f - Z_{dt-1}^f) + Z_{ft}^d - Z_{ft-1}^d. \tag{22}$$

For t$\geq$1, the foreign government's budget constraint is

$$I_{t-1}^f B_{t-1}^f = M_t^f - M_{t-1}^f + B_t^f - (1/e_t)(Z_{ft}^d - Z_{ft-1}^d) + Z_{dt}^f - Z_{dt-1}^f. \tag{23}$$

I consider the following choice of government policies. For t$\geq$1, each country is free to set (once and for all) a constant rate of growth for its money supply; that is

$$M_{t+1}^d / M_t^d \equiv \sigma^d; t \geq 1, \tag{24}$$
$$M_{t+1}^f / M_t^f \equiv \sigma^f; t \geq 1, \tag{25}$$

where $\sigma^d > 1$ and $\sigma^f > 1$. The quantities of money held by initial old agents in the domestic (foreign) economy are also given and equal $M_0^d > 0$ ($M_0^f > 0$). For reasons that will become apparent, M_1^d and M_1^f must be determined endogenously. Further, initial foreign exchange reserve holdings are given as $Z_{d0}^f = Z_{f0}^d = 0$. I allow each government to assume an endogenously determined reserve position Z_{d1}^f (Z_{f1}^d) at t=1, which it then maintains forever. Thus

$$Z_{dt}^f = Z_{dt-1}^f; t \geq 2, \tag{26}$$
$$Z_{ft}^d = Z_{ft-1}^d; t \geq 2. \tag{27}$$

Finally, $B_0^d = B_0^f = 0$ is the last initial condition; from t=1 onwards the values B_t^d and B_t^f are endogenously determined.

Under this specification of government policies, it is possible to rewrite the government budget constraints in the following, more convenient, form:

$$R_{dt-1}^d b_{t-1}^d = m_t^d - m_{t-1}^d (p_{t-1}^d / p_t^d) + b_t^d; t \geq 2, \tag{28}$$
$$R_{ft-1}^f b_{t-1}^f = m_t^f - m_{t-1}^f (p_{t-1}^f / p_t^f) + b_t^f; t \geq 2. \tag{29}$$

Observing that, by definition, $p^d_{t-1}/p^d_t \equiv (m^d_t/M^d_t)(M^d_{t-1}/m^d_{t-1}) \equiv m^d_t/\sigma^d m^d_{t-1}$ $[p^f_{t-1}/p^f_t \equiv (m^f_t/M^f_t)(M^f_{t-1}/m^f_{t-1}) \equiv m^f_t/\sigma^f m^f_{t-1}]$ for t≥1, (28) and (29) may be further simplified:

$$R^d_{dt-1}b^d_{t-1} = m^d_t(\sigma^d - 1)/\sigma^d + b^d_t; t \geq 2, \tag{30}$$

$$R^d_{dt-1}(x_{t-1}/x_t)b^f_{t-1} = m^f_t(\sigma^f - 1)/\sigma^f + b^f_t; t \geq 2, \tag{31}$$

where I have used (13′) to eliminate R^f_{ft-1} from (31). At t=1

$$M^d_0 = M^d_1 + B^d_1 - e_1 Z^f_{d1} + Z^d_{f1}, \tag{32}$$

$$M^f_0 = M^f_1 + B^f_1 - (1/e_1)Z^d_{f1} + Z^f_{d1}, \tag{33}$$

are the government budget constraints.

3.4.2 Asset Markets

In order for asset markets to clear, it is necessary that the per capita supply of real balances by the domestic (foreign) government at t - m^d_t (m^f_t) - equal the per capita demand for domestic (foreign) real balances by the residents of each country at that date. The (per capita) demand for domestic (foreign) real balances at t is just $m^d_{dt} + m^d_{ft} \equiv \gamma^d_{dt}y^d + \gamma^f_{dt}y^f x_t = \pi^d_d y^d + \pi^f_d y^f x_t[m^f_{ft} + m^f_{dt} \equiv \gamma^f_{ft}y^f + \gamma^d_{ft}y^d/x_t = \pi^f_f y^f + \pi^d_f y^d/x_t]$. Thus money market clearing requires that

$$m^d_t = \pi^d_d y^d + \pi^f_d y^f x_t; t \geq 1, \tag{34}$$

$$m^f_t = \pi^f_f y^f + \pi^d_f y^d/x_t; t \geq 1. \tag{35}$$

In order for bond markets to clear, an absence of arbitrage opportunities requires that the uncovered interest parity condition (13) or (13′) hold at each date. In addition, the total per capita supply of bonds - measured in a common unit - must equal the total per capita demand for bonds at each date. The former quantity is $b^d_t + b^f_t x_t$ - measured in units of domestic goods - while the latter is $(1 - \pi^d_d - \pi^d_f)y^d + (1 - \pi^f_f - \pi^f_d)y^f x_t$ at t. Thus bond market clearing requires that

$$b^d_t + b^f_t x_t = (1 - \pi^d_d - \pi^d_f)y^d + (1 - \pi^f_f - \pi^f_d)y^f x_t; t \geq 1. \tag{36}$$

For future reference I note that (34)-(36) imply that the total value of assets at each date - measured in a common unit - must equal the total demand for assets; that is,

$$m^d_t + b^d_t + x_t(m^f_t + b^f_t) = y^d + y^f x_t; t \geq 1. \tag{37}$$

3.4.3 Goods Market Clearing

In order for the domestic (foreign) goods market to clear at each date it is necessary that the per capita supply of domestic (foreign) goods - y^d (y^f) - equal the per capita demand for domestic (foreign) goods. But per person goods demand in (either location in) the domestic (foreign) country at t is simply the real income of domestic (foreign) residents who were *not* relocated at t-1, plus the value of real balances carried by agents who were relocated at t-1. The income of agents who were not relocated is simply the interest income generated by their (intermediated) holding of bonds, which in the domestic (foreign) country is $R^d_{dt-1}(1-\gamma^d_{dt-1}-\gamma^d_{ft-1})y^d = R^d_{dt-1}(1-\pi^d_d-\pi^d_f)y^d$ $[R^f_{ft-1}(1-\gamma^f_{ft-1}-\gamma^f_{dt-1})y^f = R^f_{ft-1}(1-\pi^f_f-\pi^f_d)y^f]$ at t. For agents who were relocated at t-1, they have arrived in their current location carrying the entire t-1 per capita supply of domestic (foreign) real balances - m^d_{t-1} (m^f_{t-1}) - which at t has a real value of $m^d_{t-1}(p^d_{t-1}/p^d_t)$ $[m^f_{t-1}(p^f_{t-1}/p^f_t)]$. Thus the domestic goods market clears at t if

$$y^d = m^d_{t-1}(p^d_{t-1}/p^d_t) + (1-\pi^d_d-\pi^d_f)y^d R^d_{dt-1}; t \geq 2, \tag{38}$$

while the foreign goods market clears if

$$y^f = m^f_{t-1}(p^f_{t-1}/p^f_t) + (1-\pi^f_f-\pi^f_d)y^f R^f_{ft-1}; t \geq 2. \tag{39}$$

By using the relations $p^d_{t-1}/p^d_t \equiv m^d_t/\sigma^d m^d_{t-1}$, $p^f_{t-1}/p^f_t \equiv m^f_t/\sigma^f m^f_{t-1}$ and (13′), these conditions can be simplified to

$$y^d = (\pi^d_d y^d + \pi^f_d y^f x_t)/\sigma^d + (1-\pi^d_d-\pi^d_f)y^d R^d_{dt-1}; t \geq 2, \tag{40}$$

$$y^f = (\pi^f_f y^f + \pi^d_f y^d/x_t)/\sigma^f + (1-\pi^f_f-\pi^f_d)y^f R^d_{dt-1}(x_{t-1}/x_t); t \geq 2.^{13} \tag{41}$$

For t≥2, equation (13) or (13′), equations (34)-(36), equations (40) and (41), and the two government budget constraints (30) and (31) constitute the complete set of equilibrium conditions for this econony. Walras' Law implies (and it is straightforward to show) that only seven of these conditions are linearly independent. However, I display all nine since all of them will be useful at some point in the analysis.

3.4.4 The Initial Period

The asset market clearing conditions at t=1 have the same form as the asset market clearing conditions that are relevant at other dates, as indicated by (13) and (34)-(36). This is not true, however, for the goods market clearing conditions at t=1, since old agents have no bond income in the initial period. Rather, at t=1, old agents have arrived in their present location by whatever means, and in the domestic (foreign) country hold the initial domestic (foreign) supply of money to private agents M_0^d (M_0^f). All of this is spent on consumption, yielding the time 1 market clearing conditions

$$M_0^d/p_1^d = y^d, \tag{42}$$

$$M_0^f/p_1^f = y^f. \tag{43}$$

Thus, the initial price levels are predetermined. This is why the time 1 period money supplies, nominal bond supplies and foreign exchange positions of each government must be endogenously determined. In particular, in the intial period each government must adapt to the predetermined price level that it confronts.

3.5 Characterization Of Equilibrium: Flexible Exchange Rates

I now turn attention to a characterization of the equilibria described in Section 3.4. I begin by analyzing steady state equilibria.

3.5.1 Steady State Equilibria

When x_t and R_{dt}^d are constant (at x and R_d^d), equations (40) and (41) reduce to two equations in those two unknowns. They therefore jointly determine the steady state values of the real exchange rate and the real interest rate. The remainder of the steady state equilibrium values can then be determined recursively: equations (34) and (35) give the steady state values of m^d and m^f, while (30) and (31) give

$$b^d = (\sigma^d - 1)m^d/\sigma^d(R_d^d - 1), \tag{44}$$

$$b^f = (\sigma^f - 1)m^f/\sigma^f(R_d^d - 1). \tag{45}$$

Moreover, clearly $p_{t+1}^d/p_t^d = \sigma^d$ and $p_{t+1}^f/p_t^f = \sigma^f$ hold, while p_1^d and p_1^f are given by equations (43) and (44). $I^d = R_d^d\sigma^d$ gives a Fisherian determination of the nominal interest rate in the domestic country, while (13) and $e_{t+1}/e_t \equiv (x_{t+1}/x_t)(p_{t+1}^f/p_t^f)(p_t^d/p_{t+1}^d) = \sigma^d/\sigma^f$ imply that the foreign nominal interest rate is $I^f = I^d(\sigma^f/\sigma^d) = R_d^d\sigma^f = R_f^f\sigma^f$ (in the steady state).

It is possible for this economy to reach its steady state equilibrium at t=1, so that $x_1 = x$. In order to support the predetermined price levels as a part of this equilibrium, M_1^d and M_1^f must be set so that

$$M_1^d/p_1^d \equiv (M_1^d/M_0^d)y^d = m^d = \pi_d^d y^d + \pi_d^f y^f x, \tag{46}$$

$$M_1^f/p_1^f \equiv (M_1^f/M_0^f)y^f = m^f = \pi_f^f y^f + \pi_f^d y^d/x, \tag{47}$$

where the first equalities follow from (42) and (43). From the government budget constraints (30) and (31), and the bond market clearing condition (36), B_1^d and B_1^f must likewise be set to satisfy $B_1^d/p_1^d = b^d$ and $B_1^f/p_1^f = b^f$.

It remains to show that the endogenously determined initial levels of foreign exchange reserves constitute an equilibrium. To do so I must show that the net foreign reserve positions of the two governments sum to zero at each date. Clearly, since I have imposed that the initial foreign exchange positions are preserved for t≥2, it suffices to show that the governments' net reserve positions sum to zero at t=1. From (32),

$$(e_1 Z_{d1}^f - Z_{f1}^d)/p_1^d = m^d + b^d - M_0^d/p_1^d = m^d + b^d - y^d, \tag{48}$$

while from (33)

$$(Z_{f1}^d - e_1 Z_{d1}^f)/e_1 p_1^f = m^f + b^f - M_0^f/p_1^f = m^f + b^f - y^f. \tag{49}$$

Multiplying both sides of (49) by x and summing (48) and (49) yields

$$0 = [(e_1 Z_{d1}^f - Z_{f1}^d) + (Z_{f1}^d - e_1 Z_{d1}^f)]/p_1^d = m^d + b^d + x(m^f + b^f) - y^d - xy^f \tag{50}$$

which is satisfied by (37). Thus the net foreign exchange positions of the two governments sum to zero, as required.

It is therefore the case that, once x and R_d^d are determined, all other steady state equilibrium quantities can be recovered. I turn next to an analysis of the determination of these values.

3.5.2 Characterization

The steady state version of equations (40) and (41) can be rearranged to yield the equivalent conditions

$$xy^f/y^d = [\sigma^d - \pi_d^d - (1 - \pi_d^d - \pi_f^d)\sigma^d R_d^d]/\pi_d^f, \tag{51}$$

$$xy^f/y^d = \pi_f^d/[\sigma^f - \pi_f^f - (1 - \pi_f^f - \pi_d^f)\sigma^f R_d^d]. \tag{52}$$

Equation (51) describes a downward sloping locus, as depicted in Figure 3.2, while equation (52) describes an upward sloping locus, shown in the same Figure. Evidently, then, (51) and (52) have a unique intersection at a positive value of x iff $(\sigma^d - \pi_d^d)/\pi_d^f > \pi_f^d/(\sigma^f - \pi_f^f)$.

While this restriction on parameter values is necessary for the existence of a steady state equilibrium it is not sufficient. In particular, the analysis of the banks' problems in Section 3.3 was predicated on $I^d = \sigma^d R_d^d > 1$ and $I^f = \sigma^f R_d^d > 1$ holding in equilibrium. Thus, a necessary and sufficient condition for the existence of a unique steady state equilibrium is that the solution to equations (51) and (52) satisfy

$$R_d^d > max(1/\sigma^d, 1/\sigma^f). \quad (53)$$

A necessary and sufficient condition for (53), in turn, is that (51) lie above (52) at the point $R_d^d = max(1/\sigma^d, 1/\sigma^f)$; this is implied by the following two assumptions, which I maintain throughout the remainder of the analysis:

(A.1) $(\sigma^d + \pi_f^d - 1)/\pi_d^f > \pi_f^d/[\sigma^f - \pi_f^f - \sigma^f(1 - \pi_f^f - \pi_d^f)/\sigma^d]$,

(A.2) $[\sigma^d - \pi_d^d - \sigma^d(1 - \pi_d^d - \pi_f^d)/\sigma^f]/pi_d^f > \pi_f^d/(\sigma^f + \pi_d^f - 1)$.

(A.1) and (A.2) require that rates of money growth must be sufficiently large for positive nominal interest rates to be observed. As such, these constitute standard assumptions. Under them, equations (51) and (52) have the configuration depicted in Figure 3.2, and they determine a unique steady state equilibrium with strictly positive nominal interest rates.

3.5.3 Comparative Statics

In the following three subsections, I consider the comparative static consequences - for steady state equilibria - of changes in the money growth rate of each country, of changes in the relative output levels in the two countries, and of changes in liquidity preference paramaters respectively. As indicated by equations (51) and (52), these are the fundamental determinants of both real exchange rates and real interest rates in this economy.

3.5.4 Comparative Statics: Money Growth Rates

The result of an increase in the rate of domestic money growth is (partially) depicted in Figure 3.3. For real interest rates satisfying $1 > (1 - \pi_d^d - \pi_f^d)R_d^d$ - which includes any equilibrium real interest rate - an increase in σ^d shifts the locus defined by (51) up and to the right in Figure 3.3. Since the locus defined by (52) is unaffected by σ^d, the evident consequence is that an increase in the money growth rate of the domestic country causes an increase in the domestic country's real exchange rate and an increase in the (world) real rate of interest. Since an increase in σ^d leads to an increase in R_d^d, clearly it also leads to an increase in I^d (and I^f). The fact that the real rate is affected by the increase in σ^d also implies that the nominal interest rate in the domestic country rises by more than the increase in the rate of inflation.

The rise in the real interest rate is due to the fact that money creation finances debt repayments. The increase in the real rate then raises the real income and demand of bond holders in both countries but, in particular, engenders an increase in the *relative* demand for foreign goods. For foreign and domestic goods markets to be simultaneously re-equilibriated there is a reallocation of purchasing power away from domestic consumers of foreign goods and towards foreign consumers of domestic goods; a real depreciation of the domestic country's currency. Notably, then, monetary changes cause both intra-national and inter-national redistributions of real income and consumption.

The nominal exchange rate effects of a rise in σ^d can be deduced as follows. Since the initial real exchange rate - x_1 - equals x, the change in the initial nominal exchange rate, $e_1 = x_1 p_1^d / p_1^f$, is given by

$$(\partial e_1/\partial\sigma^d)(\sigma^d/e_1) = (\partial p_1^d/\partial\sigma^d)(\sigma^d/p_1^d) - (\partial p_1^f/\partial\sigma^d)(\sigma^d/p_1^f) + (\partial x_1/\partial\sigma^d)(\sigma^d/x_1) \qquad (54)$$

The fact that p_1^d and p_1^f are predetermined implies that $\partial p_1^d/\partial\sigma^d = \partial p_1^f/\partial\sigma^d = 0$; hence a change in the rate of domestic money growth induces the same proportional change in the real and initial nominal exchange rates. The nominal exchange rate then rises at the rate σ^d/σ^f to keep the real exchange rate constant at its new steady state value given (new) rates of price inflation.

The effect of an increase in σ^f is depicted in Figure 3.4. Evidently, an increase in σ^f does not affect the position of the locus defined by (51), while it shifts the locus defined by (52) down and to the right (for values of R_d^d satisfying $1 > (1 - \pi_f^f - \pi_d^f)R_d^d$, which includes the equilibrium value of R_d^d). Thus an increase in the rate of growth of the foreign money stock causes the real exchange rate of the domestic country to fall, while it causes the (world) real interest rate to rise - as a consequence of the same mechanisms described above. The effect on nominal interest rates, and on the initial nominal exchange rate, induced by an increase in σ^f is analyzed exactly as before. Thus, a rise in σ^f causes the initial nominal exchange rate, e_1, to fall in proportion to the decline in the real exchange rate.

In short, increases in the rate of money growth in either country raise the (world) real interest rate and depreciate the real value of that country's currency.

3.5.5 Comparative Statics: Relative Output Levels

An examination of equations (51) and (52) indicates that an increase in the ratio y^f/y^d affects neither the real rate of interest nor the equilibrium level of xy^f/y^d. Thus an increase in y^f/y^d leads to a proportional decline in the domestic country's real exchange rate. Here, however, there is *no* change in the nominal exchange rate, as the change in y^f/y^d induces a proportional change in the ratio p_1^f/p_1^d (see equations (42) and (43)). In this sense, the initial impact of a change in relative output levels on the nominal exchange rate (zero) differs substantially from the initial impact of a change in (either) rate of money growth.

3.5.6 Comparative Statics: Liquidity Preference Parameters

The relocation probabilities, $\pi_d^d, \pi_f^d, \pi_f^f$ and π_d^f govern the composition of money holdings between domestic and foreign real balances in each country. Thus a change in any of these parameters affects the composition of money demand in either country. Here I analyze the consequences of a reduction in π_d^d; the consequences of changes in other relocation probabilities is analyzed similarly.

For values of $R_d^d > 1/\sigma^d$ (and hence for equilibrium values), a reduction in π_d^d causes the locus defined by (51) to shift in a manner similar to that associated with an increase in σ^d. Since π_d^d does not appear in equation (52), a fall in π_d^d has the same qualitative impact as an increase in the domestic country's rate of money growth. This should be an intuitive result, since a decline in π_d^d lowers the demand (ceteris paribus) for real balances of the domestic country; this has the same qualitative consequences as a monetary expansion by that country.

3.5.7 An Example: The Case Of A Small Open Economy

The case of a small open economy is particularly simple to analyze; here we consider the case where the domestic country is 'small'. By 'small' I mean that the domestic country parameters have no consequences for real (or nominal) interest rates - or prices - in the foreign country. This situation arises iff $\pi_f^d = 0$, which I now assume. This restriction implies that small country residents hold no foreign currency, and may be interpreted as the case in which small country demand for large country goods constitutes a negligible fraction of the total demand for large country goods.

When $\pi_f^d = 0$ and $x_t = x_{t-1}$ hold, equation (41) reduces to, in a steady state equilibrium,

$$R_d^d = R_f^f = (\sigma^f - \pi_f^f)/\sigma^f(1 - \pi_f^f - \pi_d^f). \tag{55}$$

Substituting this into (40) then yields

$$xy^f/y^d = (1/\pi_d^f)[(\sigma^d - \pi_d^d) - (1 - \pi_d^d)\sigma^d(\sigma^f - \pi_f^f)/\sigma^f(1 - \pi_f^f - \pi_d^f)] \tag{56}$$

which, like (51), represents a downward sloping locus in (x, R_d^d) space. While, from (55), the foreign country's parameters alone determine the world real interest rate, both domestic and foreign country factors influence the steady state real exchange rate.

Evidently, then, an increase in σ^d does not affect R_d^d, and hence an increase in the domestic money growth rate has the usual 'Fisher effect' on the domestic nominal interest rate. Moreover, from (56),

$$(\sigma^d/x)(\partial x/\partial \sigma^d) = \sigma^d(xy^f/y^d)^{-1}[1-(1-\pi_d^d)(\sigma^f-\pi_f^f)/\sigma^f(1-\pi_f^f-\pi_d^f)]/\pi_d^f > 0 \qquad (57)$$

describes the change in the real (and initial nominal) exchange rate. Since the foreign goods market clearing locus is now independent of x (vertical at the steady state value of R_d^d), such a domestic monetary change simply raises the steady state real exchange rate.

An increase in σ^f does, of course, affect the equilibrium value of the real interest rate, as before, and it induces the following change in the real (and initial nominal) exchange rate:

$$(\sigma^f/x)(\partial x/\partial \sigma^f) = -\sigma^d(xy^f/y^d)^{-1}[(1-\pi_d^d)\pi_f^f/(\sigma^f)^2(1-\pi_f^f-\pi_d^f)\pi_d^f] < 0. \qquad (58)$$

I will later use equations (57) and (58) to compare how changes in money growth rates affect the real exchange rate under fixed versus flexible exchange rate regimes.

3.6 On The Indeterminacy Of The Real Exchange Rate

The steady state equilibrium analyzed in Section 3.5 can be thought of as a 'fundamental equilibrium'; initial price levels are determined by the supply of money in each country relative to output and, thereafter, money growth rates determine the rate of inflation.[14] In this section I show that there is a continuum of dynamical equilibria, indexed - in effect - by the initial real exchange rate x_1. In the sense just described, these are 'non-fundamental equilibria'; in all such equilibria each country has an inflation rate that permanently differs from its money growth rate. By implication, these equilibria also have the property that the nominal exchange rate deviates from its 'fundamental value' at each date.

In addition, dynamical equilibria here have the feature that the real exchange rate either appreciates or depreciates permanently. It follows that real exchange rate appreciations and depreciations can occur for 'non-fundamental' reasons.

3.6.1 Dynamical Equilibria

Solving equation (40) for R_{dt-1}^d, substituting the result into (41), and rearranging terms yields the following law of motion for x_t:

$$x_{t+1} = \frac{\pi_d^d y^d + [\sigma^f y^f(1-\pi_f^f-\pi_d^f)(\sigma^d-\pi_d^d)/\sigma^d(1-\pi_d^d-\pi_f^d)]x_t}{(\sigma^f-\pi_f^f)y^f + [\pi_d^f y^f(\sigma^f y^f)(1-\pi_f^f-\pi_d^f)/\sigma^d y^d(1-\pi_d^d-\pi_f^d)]x_t}, \qquad (59)$$

which holds for $t \geq 1$.

[14]If the economies were growing (at the same rate), inflation rates would be the difference between the rate of money growth and the (common) rate of real growth in each economy.

The equilibrium law of motion for x_t is depicted in Figure 3.5. Evidently, equation (59) has a non-negative intercept, and differentiation of (59) yields the following slope for the equilibrium law of motion:

$$dx_{t+1}/dx_t = \frac{(\frac{\sigma^f y^f}{\sigma^d y^d})(\frac{1-\pi_f^f-\pi_d^f}{1-\pi_d^d-\pi_f^d})[(\sigma^d - \pi_d^d)y^d - \pi_d^f y^f x_{t+1}]}{(\sigma^f - \pi_f^f)y^f + [\pi_d^f y^f(\sigma^f y^f)(1-\pi_f^f-\pi_d^f)/\sigma^d y^d(1-\pi_d^d-\pi_f^d)]x_t}. \tag{60}$$

Since the steady state equilibrium satisfies $(\sigma^d - \pi_d^d)/\pi_d^f > xy^f/y^d$ (see Figure 3.2), it is apparent that $dx_{t+1}/dx_t > 0$ holds at any non-zero intersection of (59) with the 45^0 line. The same condition implies that - at such an intersection - $dx_{t+1}/dx_t < 1$ holds. This confirms the uniqueness of the steady state and establishes that it is asymptotically stable.

The asymptotic stability of the steady state equilibrium, of course, implies that the equilibrium real exchange rate is indeterminate; there is a continuum of possible choices for the initial exchange rate, x_1, all of which imply different perfect foresight paths.[15] Some such equilibrium paths are depicted in Figure 3.5. All such paths have the feature that the real exchange rate either appreciates or depreciates permanently.

Once x_1 is chosen, the time path for x_t is fully determined. Equation (40) then yields the sequence R_{dt}^d, while m_t^d and m_t^f are determined by (34) and (35). Equation (36) gives the equilibrium sequence $b_t^d + b_t^f x_t$; the real bond values outstanding of the individual countries are indeterminate (and irrelevant to allocations), and need be selected only to satisfy the government budget constraints. The next section explores the properties of the equilibrium rates of inflation in the two countries.

3.6.2 Inflation Rates In Non-Stationary Equilibria

Equation (34) implies that

$$M_t^d/p_t^d = m_t^d = \pi_d^d y^d + \pi_d^f y^f x_t; t \geq 1. \tag{61}$$

Thus

$$p_t^d/p_{t+1}^d = [(\pi_d^d y^d + \pi_d^f y^f x_{t+1})/(\pi_d^d y^d + \pi_d^f y^f x_t)]; t \geq 1, \tag{62}$$

also holds. If $x_1 < x$ (where x is the steady state equilibrium value of the real exchange rate), then x_t is an increasing sequence; it follows that $p_t^d/p_{t+1}^d > 1/\sigma^d$. In other words, the domestic

[15] I should note that arbitrary choices of initial x may not be consistent with equilibrium. In particular, the choice of x_1 must produce a pair of nominal interest rate sequences I_t^d, I_t^f satisfying I_t^d, I_t^f >1 for all t. Satisfaction of this requirement is guaranteed if x_1 is selected sufficiently close to x.

country's inflation rate will be *permanently below* its rate of money growth when its currency is experiencing (permanent) real depreciation in equilibrium. Similar reasoning applied to equation (35) establishes that

$$p^f_{t+1}/p^f_t = \sigma^f[(\pi^f_f y^f + \pi^d_f y^d/x_t)/(\pi^f_f y^f + \pi^d_f y^d/x_{t+1})] > \sigma^f; t \geq 1 \tag{63}$$

holds. Clearly, these inequalities will be reversed if $x_1 > x$ is observed, since then x_t will be a decreasing sequence.

3.6.3 Nominal Exchange Rate Depreciation

By definition,

$$x_{t+1}/x_t \equiv (e_{t+1}/e_t)(p^f_{t+1}/p^f_t)(p^d_t/p^d_{t+1}) \tag{64}$$

holds. Using (62) and (63) in (64) gives (upon rearranging terms)

$$e_{t+1}/e_t = (\sigma^d/\sigma^f)(\pi^d_d y^d + \pi^f_d y^f x_t)(\pi^d_f y^d + \pi^f_f y^f x_{t+1})/(\pi^d_d y^d + \pi^f_d y^f x_{t+1})(\pi^d_f y^d + \pi^f_f y^f x_t); t \geq 1. (65)$$

If $x_1 < x$, then it is straightforward to verify that $e_{t+1}/e_t > \sigma^d/\sigma^f$ holds, $\forall t \geq 1$, iff

$$\pi^d_d \pi^f_f > \pi^d_f \pi^f_d. \tag{66}$$

This condition is satisfied if the probability of within country relocation exceeds the probability of cross-country relocation, and it certainly holds if either of the two countries is 'small' in the sense defined in Section 3.5.

Equations (62), (63) and (65) yield a set of empirically testable implications that apply to non-stationary equilibria. Specifically, countries whose real exchange rate is rising should - ceteris paribus - have a lower inflation rate relative to their rate of money growth than countries whose real exchange rate is falling. If (66) is satisfied, the rate of nominal exchange rate depreciation for such countries should be high compared to their relative rate of money growth in contrast to that of countries whose real exchange rate is falling.

3.6.4 Discussion

This analysis predicts that, in non-stationary equilibria that are undisturbed by changes in exogenous variables, any country's real exchange rate should either rise or decline monotonically. Edwards (1989), in a study of real exchange rate behaviour in 33 developing countries, reports that the time path of the real exchange rate in each country almost always fits one of four patterns. Either the real exchange rate rises or declines (with minor exceptions) monotonically, or the real exchange rate rises (declines) almost monotonically up until some date, and then experiences an (almost) montonic reversal.

The first two patterns are clearly consistent with the real exchange rate behaviour predicted here, and the last two are as well in the presence of an unanticipated exogenous event. In particular, suppose that a country has a rising real exchange rate, and that at some date T, an unanticipated exogenous event reduces the new steady state exchange rate below x_T. At this point there is a free choice of 'initial conditions'; one possibility is that there is no change in the real exchange rate at time T. Since the real exchange rate will be above its new steady state value, the real exchange rate must monotonically decline after that date. This is very consistent both with the empirical findings reported in Edwards (1989, pp. 104-5), and with his interpretation of those findings.

As the foregoing discussion suggests, exogenous events can clearly be accompanied by 'overshooting' or 'undershooting' of real and nominal exchange rates. Thus such phenomena are also consistent with the present analysis.

3.6.5 A Conjecture

The close relationship between the asymptotic stability of steady state equilibria with money, on the one hand, and the existence of sunspot equilibria on the other is a common theme of the sunspot literature.[16] The construction of sunspot equilibria in this context would not be straightforward, and therefore an investigation of this connection in this model is left as a topic for future investigation. However, I conjecture that it is possible for there to be equilibria where the real exchange rate displays sunspot fluctuations. These fluctuations, if they can be observed, would then be transmitted to the nominal exchange rate and to the price levels of the individual countries.

3.7 Fixed Exchange Rates

This section describes the determination of a steady state equilibrium under a regime of fixed exchange rates. Thus, in this section, I assume that $e_t = e \forall t \geq 1$ is given and fixed. How this exchange rate is maintained will generally matter; therefore I begin with a description of government policy. The policy regime I analyze is meant to resemble the Bretton Woods system in its central features; in particular, I assume that one (large) country is free to set its own money growth rate and that all other countries 'accomodate' their rates of money growth in order to maintain the fixed nominal exchange rate target.

[16] See, for instance, Azariadis (1981), Peck (1988) and Woodford (1984).

3.7.1 Government Activity

I assume that the foreign country is free to select its own monetary policy (within the limits implied by the existence of an equilibrium), and that it behaves exactly as described in Section 3.4. Thus, $M_0^f > 0$ is given and fixed, and the foreign country selects a value σ^f that governs its money growth rate after the first period; that is,

$$M_{t+1}^f / M_t^f \equiv \sigma^f > 1; t \geq 1. \tag{67}$$

M_1^f must be endogenous as before.

The domestic country must adjust the time path of its money supply in order to maintain the fixed nominal exchange rate at each date. At t=1 this is accomplished by levying a lump-sum tax of τ_1 (in real terms) on the initial old agents; thereafter M_1^d is endogenous, and

$$M_{t+1}^d / M_t^d \equiv \sigma^d = \sigma^f; t \geq 1 \tag{68}$$

must be satisfied in a steady state equilibrium (which is clear from (13) and (13′) when $e_{t+1}/e_t = 1$ and $x_{t+1}/x_t = 1$).

In the initial period, (44) determines p_1^f. Once the initial real exchange rate x_1 is determined (see below), $p_1^d = ep_1^f / x_1$ must hold. Thus τ_1 must be selected so that

$$M_0^d / p_1^d - \tau_1 = x_1 M_0^d / ep_1^f - \tau_1 = x_1 M_0^d y^f / M_0^f - \tau_1 = y^d. \tag{69}$$

3.7.2 A Steady State Equilibrium

The set of steady state equilibrium conditions is exactly as described in Section 3.4, except that equation (69) replaces (42). In addition, $\sigma^d = \sigma^f$ holds. Thus a steady state equilibrium satisfies (51) and (52) when $\sigma^d = \sigma^f$ is imposed; that is

$$xy^f / y^d = [\sigma^f - \pi_d^d - (1 - \pi_d^d - \pi_f^d)\sigma^f R_d^d] / \pi_d^f, \tag{70}$$

$$xy^f / y^d = \pi_f^d / [\sigma^f - \pi_f^f - (1 - \pi_f^f - \pi_d^f)\sigma^f R_d^d]. \tag{71}$$

Equations (70) and (71) have a unique solution (depicted in Figure 3.2) which satisfies $R_d^d \sigma^f > 1$ iff

(A.3) $((\sigma^f + \pi_f^d - 1)/\pi_d^f) > \pi_f^d / (\sigma^f + \pi_d^f - 1).$ [17]

[17](A.3) is just (A.1) *and* (A.2) with $\sigma^d = \sigma^f$ imposed.

Evidently, the choice of the fixed nominal exchange rate value has no implications for the equilibrium real exchange rate, or indeed, for any equilibrium quantities other than the domestic price level. This result is of some importance, since in discussions of the EMS[18] it is often suggested that the nominal exchange rate between currencies should be selected (given initial price levels) to yield (approximate) purchasing power parity. Since purchasing power parity will (generically) not hold at any date (or asymptotically) here, such policies will *not* prevent the necessity of domestic price level adjustments. Here such adjustements would be accomplished by varying τ_1.

Once the equilibrium values of x and R_d^d are determined, all other equilibrium quantities (except p_1^d) are determined as in Section 3.5. As noted, all of these - except for the domestic price level sequence p_t^d - are determined independently of the choice of e.

3.7.3 Comparative Statics

In this section, I analyze the steady state equilibrium consequences of a change in the (common) money growth rate, σ^f. These will generally differ from the consequences of changes in either the domestic or foreign money growth rates in the flexible exchange rate case, since here both money growth rates must move together. Other comparative static results do coincide with the flexible exchange rate case; therefore they are not reconsidered here.

As will be demonstrated, the effects of a change in σ^f for the real exchange rate are necessarily ambiguous since both the domestic and foreign goods markets are affected. To simplify calculations, I henceforth confine attention to the case where the domestic country is 'small'. Thus, in the remainder of this section, I assume that π_f^d=0. This case is adequate to illustrate the general tenor of the results obtained.

When π_f^d=0 holds, equation (55) continues to describe determination of the real interest rate. (56) gives the real exchange rate when $\sigma^d = \sigma^f$ is imposed; that is

$$xy^f/y^d = [(\sigma^f - \pi_d^d) - (1 - \pi_d^d)(\sigma^f - \pi_f^f)/(1 - \pi_f^f - \pi_d^f)]/\pi_d^f. \tag{72}$$

Thus

$$\partial R_d^d/\partial\sigma^f = \pi_f^f R_d^d/\sigma^f(\sigma^f - \pi_f^f) > 0, \tag{73}$$

and

$$\partial(xy^f/y^d)/\partial\sigma^f = [1 - (1 - \pi_d^d)R_d^d]/\pi_d^f - [(1 - \pi_d^d)\sigma^f/\pi_d^f]\partial R_d^d/\partial\sigma^f. \tag{74}$$

[18]Williamson (1985, 1993) for example, discusses criteria for estimating fundamental equilibrium exchange rates in the context of countries' choices of central exchange rate values in managed rate systems (and the EMS in particular). See also Kenen (1988) and Krugman and Miller (1992).

Under flexible exchange rates

$$\partial(xy^f/y^d)/\partial\sigma^d = [1-(1-\pi_d^d)R_d^d]/\pi_d^f > 0 \tag{75}$$

$$\partial(xy^f/y^d)/\partial\sigma^f = -[(1-\pi_d^d)\sigma^f/\pi_d^f]\partial R_d^d/\partial\sigma^f < 0, \tag{76}$$

(evaluated at $\sigma^d = \sigma^f$). Since R_d^d and $\partial R_d^d/\partial\sigma^f$ are unaffected by the choice of exchange rate regime, a comparison of equations (74)-(76) indicates that

$$\partial x/\partial\sigma^d\,|_{flexible} > \partial x/\partial\sigma^f\,|_{fixed} > \partial x/\partial\sigma^f\,|_{flexible}$$

Thus, the fact that the maintenance of a fixed exchange rate requires both money growth rates to move together weakens the impact of a change in the (common) rate of money growth, relative to a regime of flexible rates. In particular, when the impact of an increase in σ^f on the real exchange rate is positive under fixed exchange rates, it is smaller than the positive impact of an equivalent change in σ^d under flexible rates. Similarly, when an increase in σ^f reduces x under fixed rates, the absolute value of the change in x is smaller than the absolute value of the (negative) change in x that would be induced by an equivalent increase in σ^f under flexible rates. This result reflects the fact that a change in the money growth rate σ^f now induces a reduction in the purchasing power over goods of currency holders in *both* countries, and requires simultaneous adjustment of the real interest rate to satisfy the government budget constraint in *both* countries. Thus, the international reallocation of purchasing power needed - in the form of real exchange rate changes - to simultaneously re-equilibriate both goods markets is reduced.

In order to obtain the sign of $\partial x/\partial\sigma^f$ in a fixed rate system, substitute (73) into (74) and rearrange terms to get

$$\begin{aligned}\partial(xy^f/y^d)/\partial\sigma^f &= [\sigma^f-\pi_f^f-(1-\pi_d^d)\sigma^f R_d^d]/\pi_d^f(\sigma^f-\pi_f^f)\\ &= xy^f/y^d(\sigma^f-\pi_f^f)-(\pi_f^f-\pi_d^d)/\pi_d^f(\sigma^f-\pi_f^f),\end{aligned} \tag{77}$$

where the last equality makes use of (55) and (72). Then

Proposition 1. (a) Suppose that $\pi_d^d \geq \pi_f^f$. Then $\partial x/\partial\sigma^f > 0$. (b) $\partial x/\partial\sigma^f < 0$ iff $(\pi_f^f-\pi_d^d)/\pi_d^f > xy^f/y^d$.

Thus, when the nominal exchange rate is fixed, an increase in the common money growth rate can either raise or lower the equilibrium real exchange rate.

3.8 Reserve Requirements And Exchange Controls

In this section I examine how the imposition of either reserve requirements or exchange controls impacts on the equilibrium values of the real (and, under flexible rates, nominal) exchange rate, and on the real rate of interest. I focus here on steady state equilibria; for fixed exchange rate regimes these are the only equilibria examined, while for flexible exchange rate regimes I have shown that any non-stationary equilibria asymptotically approach the steady state. Thus, in the latter case, the analysis of this section is informative regarding the long-run impacts of these regulations on dynamical equilibria. Finally, in order to simplify the exposition, I focus throughout on the case where the domestic country is small; thus $\pi_f^d=0$ is assumed to hold.

3.8.1 Domestic (Small) Country Reserve Requirements

Imagine that banks in the domestic country are subject to a binding reserve requirement; that is, they are obligated to hold a minimum amount of domestic currency per unit deposited. Such a requirement is represented by the regulatory restriction

$$\gamma_{dt}^d \geq \bar{\gamma}_d^d \in (\pi_d^d, 1); t \geq 1. \tag{78}$$

The assumption that $\bar{\gamma}_d^d > \pi_d^d$, of course, implies that the reserve requirement is binding.

Banks in the domestic country now must solve the problem[19]

$$(\text{P.3}) \quad \max \; \pi_d^d lnr_{dt}^d + (1-\pi_d^d) lnr_t^d$$

subject to (9) to (11), (78) and non-negativity, and where I have used the assumption $\pi_f^d=0$. The solution to this problem clearly sets $\gamma_{dt}^d = \bar{\gamma}_d^d$; the solution to the problem of banks in the foreign country is obviously unaffected. In addition, (13) must continue to hold to preclude arbitrage opportunities.

With $\pi_f^d=0$, the money market clearing conditions now become, in a steady state equilibrium, (compare with 34 and 35)

$$m^d = \bar{\gamma}_d^d y^d + \pi_d^f y^f x, \tag{79}$$
$$m^f = \pi_f^f y^f. \tag{80}$$

[19] I consider here only legal restrictions on banks that do not cause some savings to leave the banking system. Disintermediation will generally be a possibility, but only if the legal restrictions imposed on banks are sufficiently severe. Thus the focus in the text is on 'mild' but binding restrictions.

The bond market clears in a steady state equilibrium if (13) and $m^d + b^d + x(m^f + b^f) = y^d + xy^f$ hold, and goods market clearing obtains in each country in such an equilibrium if

$$y^d = m^d/\sigma^d + (1 - \bar{\gamma}_d^d)y^d R_d^d, \tag{81}$$
$$y^f = m^f/\sigma^f + (1 - \pi_f^f - \pi_d^f)y^f R_d^d. \tag{82}$$

Using (79) and (80) to eliminate m^d and m^f from (81) and (82) yields the following steady state equilibrium conditions:

$$y^d = (\bar{\gamma}_d^d y^d + \pi_d^f y^f x)/\sigma^d + (1 - \bar{\gamma}_d^d)y^d R_d^d, \tag{83}$$
$$y^f = (\pi_f^f y^f)/\sigma^f + (1 - \pi_f^f - \pi_d^f)y^f R_d^d. \tag{84}$$

Evidently, the choice of reserve requirement by the (small) domestic country has no effect on R_d^d which is determined by foreign goods market clearing alone. From (83), then,

$$\partial x/\partial \bar{\gamma}_d^d = -y^d/\pi_d^f y^f < 0.$$

This should be intuitive; an increase in the domestic country's reserve requirement raises the demand for its currency, and so its goods, with consequences opposite to those of a monetary expansion; a real appreciation of that country's currency is observed which offsets the rise in domestic goods demand with a reduction in the purchasing power of foreign consumers of those goods. Since the regulatory actions of the small, domestic economy do not affect the time path of the price level (in either country), an increase in the reserve requirement of the domestic country moves the nominal exchange rate in its favour as well under a regime of flexible exchange rates.

3.8.2 Foreign (Large) Country Reserve Requirements

I now consider the consequences of a reserve requirement imposed by the large, foreign economy. Its banks face the regulatory restriction

$$\gamma_{ft}^f \geq \bar{\gamma}_f^f \in (\pi_f^f, 1); t \geq 1. \tag{85}$$

The assumption that $\bar{\gamma}_f^f > \pi_f^f$, again, implies that the reserve requirement is binding. Domestic banks are assumed to be unencumbered by the reserve requirement.[20]

Banks in the foreign country are now faced with the problem

[20] The analysis would be unaltered if domestic banks faced a binding reserve requirement that is held fixed.

(P.4) $\max\ \pi_f^f ln r_{ft}^f + (1-\pi_f^f-\pi_d^f) ln r_t^f$,

subject to (18)-(20), (85) and non-negativity. The solution to this problem is easily shown to set $\gamma_{ft}^f = \bar{\gamma}_f^f$, and

$$\gamma_{dt}^f = \pi_d^f[(1-\bar{\gamma}_f^f)/(1-\pi_f^f)] < \pi_d^f; t \geq 1, \tag{86}$$

where (13) must continue to hold. (86) shows that a foreign country reserve requirement causes foreign country banks to reduce their holdings of domestic real balances in proportion to the rise in their holdings of foreign real balances. The same is true of their bond holdings since $(1-\gamma_{ft}^f-\gamma_{dt}^f) = (1-\pi_f^f-\pi_d^f)[(1-\bar{\gamma}_f^f)/(1-\pi_f^f)] < (1-\pi_f^f-\pi_d^f); t \geq 1$.

The money market clearing conditions in a steady state equilibrium under this regime are now

$$m^d = \pi_d^d y^d + \pi_d^f y^f x(1-\bar{\gamma}_f^f)/(1-\pi_f^f), \tag{87}$$
$$m^f = \bar{\gamma}_f^f y^f. \tag{88}$$

and, again, the bond market clears in such an equilibrium if (13) and $m^d+b^d+x(m^f+b^f) = y^d+xy^f$ hold. Goods market clearing now obtains in the steady state if

$$y^d = m^d/\sigma^d + (1-\pi_d^d)y^d R_d^d, \tag{89}$$
$$y^f = m^f/\sigma^f + (1-\bar{\gamma}_f^f-\gamma_d^f)y^f R_d^d. \tag{90}$$

From (86)-(90) the following steady state equilibrium conditions are obtained:[21]

$$y^d = (\pi_d^d y^d + \pi_d^f y^f x(1-\bar{\gamma}_f^f)/(1-\pi_f^f))/\sigma^d + (1-\pi_d^d)y^d R_d^d, \tag{91}$$
$$y^f = (\bar{\gamma}_f^f y^f)/\sigma^f + y^f R_d^d(1-\bar{\gamma}_f^f)(1-\pi_f^f-\pi_d^f)/(1-\pi_f^f). \tag{92}$$

Again, R_d^d is determined in the foreign goods market, (and so is directly affected by the imposition of a reserve requirement in the large country), while the steady state value of x follows from the domestic goods market clearing condition (91).

Straightforward differentiation of (92) yields that $\partial R_d^d/\partial\bar{\gamma}_f^f = (\sigma^f-1)R_d^d/(\sigma^f-\bar{\gamma}_f^f)(1-\bar{\gamma}_f^f) > 0$. Thus, an increase in the reserve requirement on (large) foreign country banks raises the real interest rate by causing a fall in the real value of bondholdings which more than offsets the effect for foreign goods demand of the rise in foreign country currency holdings. Upon differentiating (91), some manipulation yields

[21] It is easy to show that these conditions have a unique solution with positive nominal interest rates in each country if σ^d and σ^f are set sufficiently large.

$$\partial(xy^f/y^d)/\partial\bar{\gamma}_f^f = (xy^f/y^d) - \pi_d^f[(\sigma^f - 1)/\sigma^f](1 - \pi_d^d)/\sigma^d(1 - \pi_d^d - \pi_f^d)/(1 - \bar{\gamma}_f^f),$$

which is ambiguous in sign.

An increase in the large foreign country's reserve requirement reduces the (foreign) demand for real balances of the (small) domestic country and also, therefore, the foreign country's demand for domestic goods. This tends to raise the real exchange rate of the domestic country; a real depreciation of the domestic currency raises the purchasing power of foreign agents in domestic markets. However, the increase in the world real interest rate described above raises the income of bondholders, raising the *domestic* demand for domestic goods and so tending to *reduce* the steady state real exchange rate of the domestic country; a real appreciation of the domestic country's currency will reduce the purchasing power of foreign agents transacting in domestic goods markets. The net effect on the real exchange rate depends on the relative magnitude of these two factors. The same comment, of course, applies to the initial nominal exchange rate under a flexible nominal exchange rate regime.

Another consequence of foreign country reserve requirements is that they magnify the impact of monetary policy changes which take place in the large foreign country. In particular, a given change in σ^f has a larger impact (in absolute value) on both R_d^d and x (and hence, under flexible exchange rates, the initial nominal rate as well) when a binding reserve requirement is imposed. Thus reserve requirements can be employed not only as direct instruments of policy, but can also be used to augment the effectiveness of other policy measures.

3.8.3 Foreign (Large) Country Exchange Controls

Another common policy intervention is the imposition of controls on foreign exchange holdings. When the domestic country is small its residents hold no foreign currency; hence I consider the consequences of foreign exchange controls imposed by the large foreign country on its own residents. Such controls here take the form of a requirement that

$$\gamma_{dt}^f \leq \underline{\gamma_d^f} \in [0, \pi_d^f), \tag{93}$$

so that the fraction of the value of total assets that can be held as foreign currency is limited by regulation. The fact that $\underline{\gamma_d^f} < \pi_d^f$ implies that the foreign exchange control is binding on foreign banks.

The problem of these banks is now to maximize

(P.5) $\pi_f^f lnr_{ft}^f + \pi_d^f lnr_{dt}^f + (1 - \pi_f^f - \pi_d^f) lnr_t^f$,

subject to (18)-(20), (93) and non-negativity. The solution to this problem obviously sets $\gamma_{dt}^f = \underline{\gamma_d^f}$, and in addition,

$$\gamma_{ft}^f = \pi_f^f[(1 - \underline{\gamma_d^f})/(1 - \pi_d^f)]; t \geq 1, \tag{94}$$

holds. Thus, foreign exchange controls cause foreign country banks to increase their holdings of foreign real balances in proportion to the reduction in their holdings of domestic country real balances. Similarly, $(1 - \gamma_{ft}^f - \gamma_{dt}^f) = (1 - \pi_f^f - \pi_d^f)[(1 - \underline{\gamma_d^f})/(1 - \pi_d^f) > (1 - \pi_f^f - \pi_d^f)]; t \geq 1$.

It is straightforward to verify that - in the presence of the binding exchange control - the goods market clearing conditions in a steady state equilibrium take the form[22]

$$y^d = (\pi_d^d y^d + \underline{\gamma_d^f} y^f x)/\sigma^d + (1 - \pi_d^d) y^d R_d^d, \tag{95}$$

$$y^f = (\pi_f^f y^f (1 - \underline{\gamma_d^f})/(1 - \pi_d^f)\sigma^f) + y^f R_d^d (1 - \pi_f^f - \pi_d^f)(1 - \underline{\gamma_d^f})/(1 - \pi_d^f). \tag{96}$$

Differentiating (96),

$$\partial R_d^d / \partial \underline{\gamma_d^f} = (1 - \pi_d^f)/(1 - \pi_f^f - \pi_d^f)(1 - \underline{\gamma_d^f})^2 > 0.$$

Differentiating (95) then gives

$$\partial (x y^f / y^d)/\partial \underline{\gamma_d^f} = -(x y^f / y^d)/\underline{\gamma_d^f} - [\sigma^d (1 - \pi_d^d)/\underline{\gamma_d^f}] \partial R_d^d / \partial \underline{\gamma_d^f} < 0.$$

Thus a relaxation of exchange controls in the large foreign country (an increase in $\underline{\gamma_d^f}$) tends to raise the real interest rate and lower the real exchange rate of the domestic country. Conversely, then, the imposition or tightening of exchange controls on foreign country banks acts to reduce the real interest rate and raise the real exchange rate of the domestic country.

Reserve requirements and exchange controls imposed by a large country are not, then, equally good instruments for manipulating either real or nominal exchange rates. Notice that both an increase in reserve requirements and a tightening of exchange controls operate to raise the foreign country demand for foreign country real balances (and goods). However, the two policies have different effects on the demand for bonds and so on the real interest rate and bondholder income and demand for domestic country goods. An increase in reserve requirements acts to reduce the demand

[22]A unique steady state equilibrium with $I^d, I^f > 1$ exists if σ^d and σ^f are sufficiently large.

for bonds by foreign banks and so raises the real interest rate. The opposite effect follows from a tightening of exchange controls, which operates to raise the demand for bonds by foreign banks and so reduce the equilibrium real interest rate. Thus, increasing the stringency of foreign exchange controls unambiguously *reduces* the demand for domestic country goods (both foreign agents and bondholders now have lower real income) and therefore unambiguously *raises* the steady state equilibrium real exchange rate. This real depreciation of the domestic country's currency offsets the fall in demand by increasing the purchasing power of foreign agents over domestic goods. However, as shown above, reserve requirements engender an ambiguous real exchange rate response. This observation is suggestive of why governments often object to the imposition of exchange controls by other countries, whereas the manipulation of reserve requirements rarely draws international comment.

3.9 Conclusion

I have developed a two-country model in which spatial separation and limited communication create a role for money and in which stochastic relocation - which acts like a liquidity preference shock - creates a role for banks. Money and banking behaviour together play a central role in the determination of real and nominal exchange rates in this economy. In particular, spatial separation allows permanent deviations from purchasing power parity to be observed, and monetary factors are 'fundamental' determinants of the steady state equilibrium real exchange rate.

The model can account for at least three empirical regularities that were discussed in the introduction. First, the impact of monetary factors on real exchange rates in this economy is consistent with evidence supporting the importance of nominal disturbances for real exchange rate fluctuations. Second, the initial impact of monetary policy changes is the same for both real and nominal exchange rates, which is suggestive of why the real and nominal exchange rates appear to move together during flexible exchange rate regimes. Third, under a fixed exchange rate regime, the impact of monetary factors on the real exchange rate is muted. This is consistent with the observation that real exchange rates have been less volatile under fixed than under flexible exchange rates over the last thirty years.

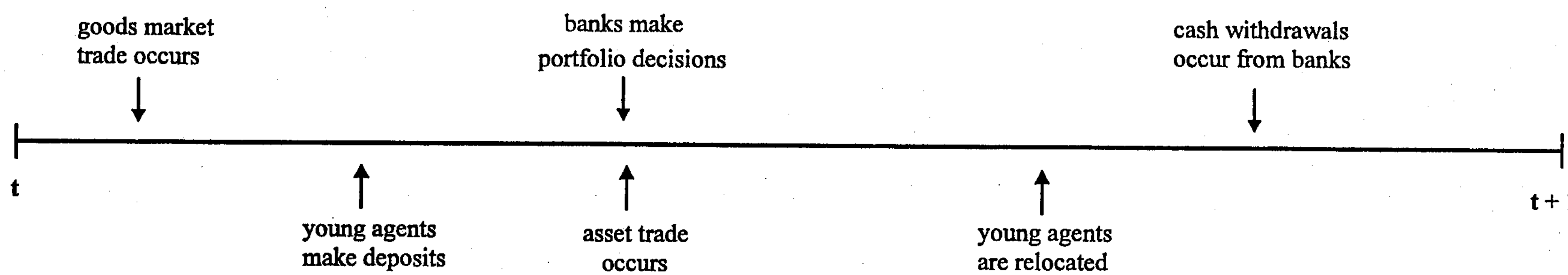
I also find that under flexible exchange rates there exists a continuum of 'non-fundamental' dynamical equilibria, so that the real *and* the nominal exchange rates are indeterminate. Dynamical equilibria have the property that cross-country differentials in real interest rates are observed, and that rates of inflation and currency depreciation deviate from what would be expected on the basis of money growth rates alone. Moreover, dynamical equilibria generate real exchange rate paths that are widely observed in data from developing countries.

The existence of a continuum of perfect foresight equilibria under flexible exchange rates is suggestive of possibilities for future investigation. For example, one can consider notions of nominal exchange rate overshooting and undershooting of the following form. Consider a world economy in a steady state equilibrium. If there is an increase in, say, the domestic country's money growth rate, this will raise the steady state real exchange rate. However, there also exists a continuum of equilibria in which the initial real exchange rate in the new equilibrium is either above or below its new steady state value, and in which the real exchange rate asymptotically converges to the new steady state from its 'over' or 'under-shot' initial level. This interpretation seems to be consistent with at least some empirical evidence on the behaviour of real exchange rates.

The model also makes a number of empirical predictions which I intend to pursue in future work. For example, under flexible exchange rates, xy^f / y^d should be positively (negatively) related to σ^d (σ^f) in the steady state (and hence in the 'long-run' under non-stationary equilibria). In addition, again under flexible exchange rates - and with reference to steady state equilibria - changes in rates of money growth initially induce an identical proportional change in real and nominal rates of exchange. The same is *not* true for changes in real factors, since these influence the initial price levels. With respect to non-stationary equilibria, countries whose real exchange rates are rising (falling) should have rates of inflation below (above) their rate of money growth (less the real rate of growth). These are implications of the model that can be easily investigated empirically.

While these results have been obtained in a model where a number of simplifying assumptions have been made, I conjecture that most of them will survive generalization. For instance, having multiple goods, with some being internationally traded and others not, is a conceptually straightforward extension. So is a consideration of more general utility functions, or an examination of a world with non-unitary savings rates. Finally, some introduction of stochastic elements is straightforward - as in Champ, Smith and Williamson (1992) - and I conjecture that some version of all of my results will obtain in such extensions.

Figure 3.1
Timing of Transactions



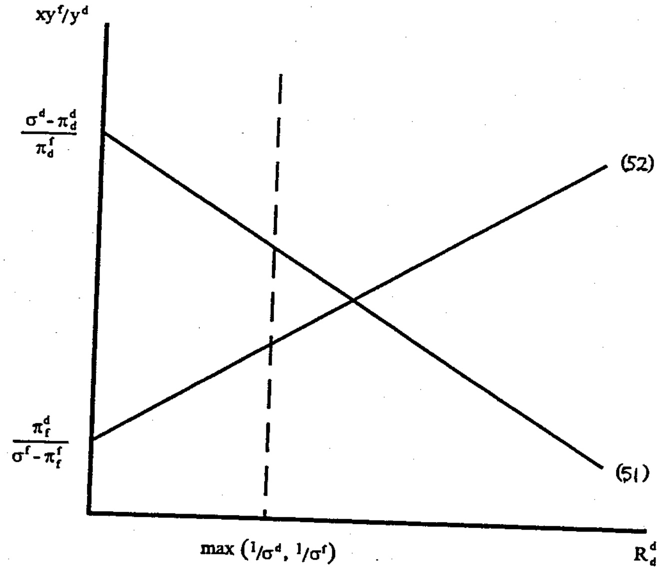


Figure 3.2

Determination of a Steady State Equilibrium

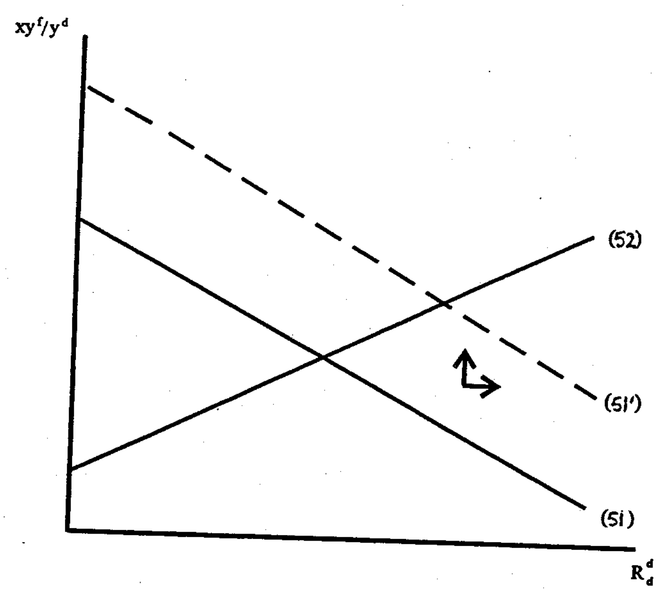


Figure 3.3

An increase in σ^d

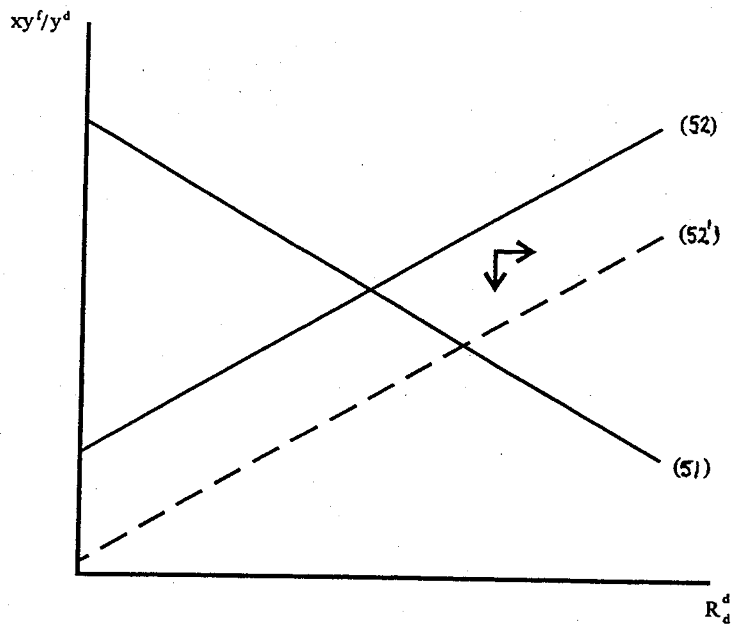


Figure 3.4

An increase in σ^f

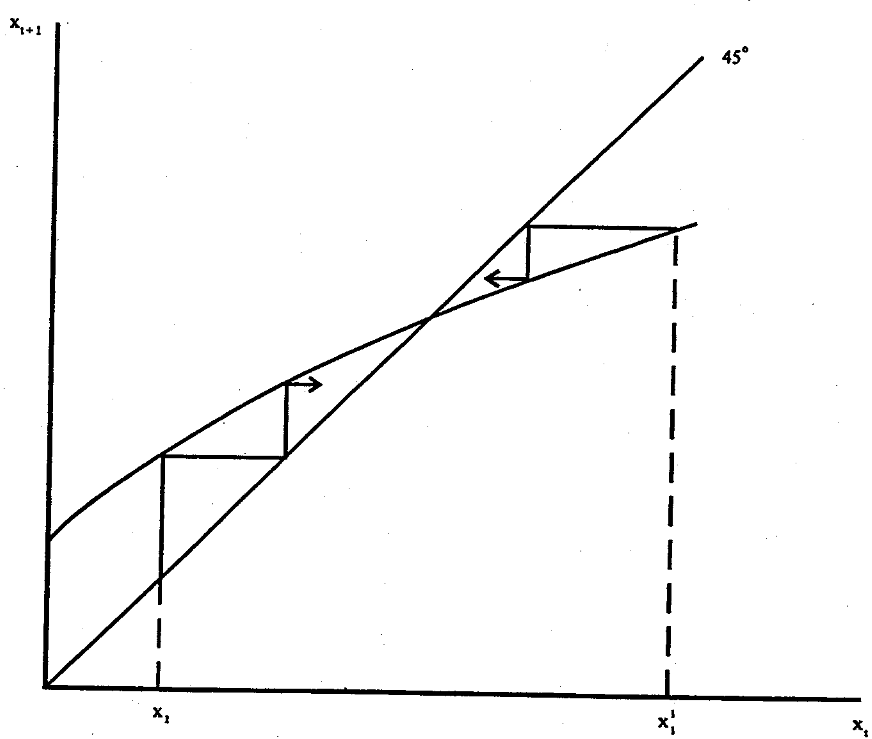


Figure 3.5

Dynamical Equilibria

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