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Common Trends and Structural Change: A Dynamic Macro Model for the Pre- and Postrevolution Islamic Republic of Iran

Prepared by Torbjörn Becker[1]

Authorized for distribution by Donald J. Mathieson

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A Dynamic Macro Model for the Pre- and Postrevolution Islamic Republic of Iran

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Abstract

This paper uses a common trends model to study how prices, the black market exchange rate, money, and real output have developed over a period covering both pre- and post-revolution Iranian data. It is shown that monetary shocks have significant short-run effects on output, but permanent effects on the price level and exchange rate, that is, expansionary monetary policy is not consistent with achieving low inflation or a stable unified exchange rate. The real shocks generate higher growth and lower inflation, suggesting that supply-side policies are consistent with the goals in the Islamic Republic of Iran's second five-year development plan.

JEL Classification Numbers: C32, E31, E41, F41

Keywords: output, inflation, exchange rate, real and nominal shocks, cointegration

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Contents | Page

I. Introduction

The purpose of this paper is twofold. The most important is to provide an empirical analysis of two highly policy relevant topics in Iran: the determinants of inflation, and what to expect when the exchange rate is unified. The second is to present a relatively new methodology to analyze such questions, namely the common trends representation of a vector of time series with cointegrating constraints.

Iran has experienced relatively high levels of inflation for several years. This has become one of the major concerns of the policy makers, and there is a strong consensus that inflation should be reduced to single digits. In order to design policies that are aimed at reducing inflation, it is obviously useful to know what its main determinants have been in the past.

Another issue that has been high on the policy agenda is the unification of the exchange rates and its management. One potential way of predicting the behavior of a future unified exchange rate is to investigate the behavior of the free/black market exchange rate to see if its behavior is reasonably consistent with standard theoretical models. If it is, it may provide a useful guideline to both the level that should be chosen for the unified rate and the determinants of the future developments of the exchange rate.

In order to investigate these questions, a common trends model including the price level, broad money, real output, the exchange rate and the foreign price level is estimated.[2] To account for important exogenous factors other than the foreign price level, the model includes the international oil price and dummies accounting for structural shifts in connection with the revolution and the Iran-Iraq war. The advantage with the employed empirical framework is that it not only explicitly deals with stationarity and long run equilibrium relationships (or cointegration) as the standard (reduced form) error correction models, but it also uses theoretical considerations to impose identifying restrictions that allow a more comprehensive study of short and long run dynamics and a structural interpretation of the innovations.

The paper finds evidence of two cointegrating vectors that are consistent with the theoretical concepts of a stable money demand function and PPP after accounting for the exogenous factors. Having combined the exchange rate and the foreign price level into one variable, and concluded that the system has two cointegrating vectors, the model is identified to have two common stochastic trends or permanent shocks, interpreted as one real (or technology) and one nominal shock, by assuming that the nominal shock does not have a long run impact on output. The remaining two transitory shocks are identified as a demand and a foreign exchange market (FEX or speculative) shock, by assuming that the FEX shock does not have an immediate impact on output. Having imposed these restrictions and assumed that the structural shocks are independent, impulse response functions and variance decompositions are derived. The results from this exercise are presented in detail in the empirical section and summarized in the concluding section.

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[2]For a similar study on South Africa, see Jonsson (1999).

The remainder of the paper is organized as follows. First there is a section familiarizing the reader with the common trends representation of a vector of time series, with particular attention paid to identification and how the interpretation of such model differs from the more familiar reduced form vector error correction specification. For the reader familiar with these more recent tools in time series analysis, the section can readily be skipped. The following short section discusses the theoretical underpinnings that will be used to determine what variables to include in the system and what the appropriate identifying assumptions are. The fourth section contains the empirical investigation, with, among other things, stationarity tests and impulse response charts. Finally, there is a concluding section summarizing the results and discussing the policy implications for Iran.

II. Methodological Framework

In most empirical studies using time-series data, the issues of non-stationarity, cointegration, simultaneity and exogeneity have to be addressed. In this paper, a vector auto regressive model with exogenous variables (or a VARX model) that explicitly deals with non-stationarity and cointegration is estimated, and by imposing identifying restrictions the (semi) structural common trends model is derived. This section provides a brief introduction of the method, with special attention devoted to the important question of identification and the links and interpretations of different ways of representing a time series model. For a more extensive treatment of the methodology, see, for example, Johansen (1991), Jacobson et al (1996), Warne (1993) in addition to King et al (1991), and for an application to fiscal policy, see Becker (1997).

Start with the familiar vector autoregressive (VAR) model that has been extended to include exogenous variables (usually labeled VARX),

$$x_t = \Pi(L)x_{t-1} + F(L)z_t + \varepsilon_t, \tag{1}$$

where x_t is a $n \times 1$ vector of endogenous variables, z_t is a $m \times 1$ vector of exogenous variables, $\Pi(L)$ and $F(L)$ are matrix polynomials, and ε_t is a $n \times 1$ vector of i.i.d. errors with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Sigma$. The VARX representation can be readily estimated by standard methods if the time series are stationary. However, this is generally a reduced form rather than a structural, and the parameters and error terms are linear combinations of the structural ones from the structural VARX (or SVARX)

$$x_t = \Pi^*(0)x_t + \Pi^*(L)x_{t-1} + F^*(L)z_t + \varepsilon_t^*, \tag{2}$$

where the contemporaneous endogenous variables appear on both sides of the equation, that is, in the structural model, innovations in one equation can have effects on the other equations within the period, and there are also possible feedback effects from the other equations into the one where the shock initially occurred. The connection between the SVARX and the VARX can be seen by collecting all x_t variables on the left-hand side, and then premultiply the entire expression by $\left(I-\Pi^{*}(0)\right)^{-1}$. This implies, for example, that $\Pi(L)=(I-\Pi^{*}(0))^{-1}\Pi^{*}(L)$, that is, the parameters in the reduced form are linear combinations of the underlying structural parameters, which is also the case for the parameters related to the exogenous variables. In the same way, the errors in the reduced form are linear combinations of the structural errors. In other words, if the first equation in the VARX has money as the left hand side variable, that does not imply that the error term associated with that equation should be interpreted as a money shock as would be justified if the structural error in the SVARX had been recovered.

In general, a number of identifying restrictions has to be imposed on the $\Pi^{*}(0)$ matrix to recover the structural parameters from the reduced form estimates. A common way of dealing with the identification issue is to impose a recursive structure on the system, that is, assume that $\Pi^{*}(0)$ is lower triangular (see, e.g., Sims 1980). However, this is not always a desirable way of identifying macro models, since there are many cases where simultaneous responses are part of the underlying model, and there are other restrictions more coherent with theoretical models that can be imposed to identify the structural parameters. The identification issue has been discussed by, for example, Cooley and LeRoy (1985), Keating (1990), Bernanke (1986), King et al (1991), and Warne (1993).

If the variables are non-stationary in the sense that they are integrated of order one, or I(1), the variables are stationary in first differences and the system can be estimated in first differences rather than in levels. However, in the case some variables have a linear combination in levels that is stationary, that is, the variables are cointegrated, some information about their long run behavior is ignored if a VARX in first differences is estimated. This motivates the use of the vector error correction (VEC) representation

$$\Delta x_t=\Gamma(L)\Delta x_{t-i}-\Pi x_{t-1}+P(L)z_t+\varepsilon_t, \qquad (3)$$

where $\Gamma_i(\lambda)=-\sum_{j=i+1}^{p}\Pi_j\lambda^j$ and $\Pi=\Pi(1)$. The lagged levels are included to allow for cointegration, and the number of cointegrating vectors can be tested by investigating the rank of the Π matrix, see Johansen (1991). If Π is of full rank, the series are stationary in levels, and in case the rank is zero, there are no cointegrating vectors. However, in the case of reduced rank ($\operatorname{rank}(\Pi)=r<n$), the Π matrix can be written as $\Pi=\alpha\beta'$, where α and β are $n\times r$ matrices, with β containing the r cointegrating vectors and α the coefficients that describe the speed of adjustment to the long run equilibria.

The VEC parameters and errors are also reduced form estimates, and do not allow structural interpretations. However, having determined the number of cointegrating vectors and estimated the coefficients of these vectors and other reduced form parameters, the (semi) structural CT representation can be derived by imposing identifying assumptions on the correlation between the structural shocks and the long run matrix A in the CT representation.

$$x_t = x_0 + A\tau_t + \Phi(L)v_t + B\sum_{i=1}^{t} z_i + D(L)z_t, \tag{4}$$

with $\tau_t = \gamma + \tau_{t-1} + \varphi_t$, which is an $k \times 1$ (with $k = n - r$) vector of the common stochastic trends, with φ_t being the structural permanent innovations. $\Phi(L)$ and $D(L)$ are matrix polynomials and v_t contains the structural errors. The structural errors can be decomposed into the k permanent shocks, φ_t, and the r transitory, ψ_t, and these are related to the reduced form errors through the identification matrix F, that is, $\varepsilon_t = Fv_t = F[\varphi_t \quad \psi_t]'$. The interpretation of the CT model is thus that a reduced number of common stochastic trends drive the variables in the long run.

The time series can be split into a permanent and a transitory component according to $X_t = X_t^P + X_t^T$, where the permanent component is $X_t^P = A\tau_t + B\sum_{i=1}^{t} Z_i$ and the transitory is $X_t^T = \Phi(L)v_t + D(L)Z_t$. Note that since the permanent shocks are part of v_t they will potentially affect also the short run through the $\Phi(L)$ polynomial. The CT model thus provides one way of decomposing a series into a "structural" and a "cyclical" component, which can be used to answer questions like what is the output gap (the transitory component of GDP) or what is the structural vs. cyclical deficit. With exogenous variables included in the system, the analysis of the endogenous series in terms of stationary and non-stationary components is conditional on the information embodied in the exogenous series. The role of the exogenous variables will be discussed more in detail when the estimated model is presented.

The vector moving average (VMA) representation corresponding to the above CT representation can be derived by further identifying assumptions on the contemporaneous responses to the transitory shocks

$$\Delta x_t = C(L)P(L)z_t + R(L)v_t, \tag{5}$$

where $C(L)$ is a matrix polynomial obtained from the VEC representation and $R(L)$ is a lag polynomial with the responses in the variables to the structural shocks φ_t at different horizons, and R_0 contains the contemporaneous responses where restrictions are imposed to identify the transitory shocks. R_1 is then the one period lagged responses and so on. The VMA representation lends itself to simulations of responses to structural shocks/innovations rather than reduced form innovations

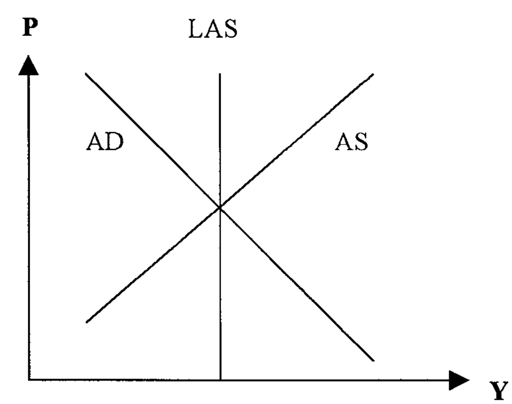
The CT model and associated VMA representation allow us to study a number of questions like:

- test of hypothesis regarding *long run equilibria* (co-integration, test of the number of vectors and their coefficients)

- are transitory or permanent shocks most important for *short run fluctuations* in a certain variable (variance decomposition)
- how are the *shocks propagated* in the system (impulse responses)
- how long does the *adjustment to equilibrium* take (impulse responses of cointegrating relationships)
- what are the *structural vs. cyclical component*s of a variable (permanent vs. transitory components)

To illustrate the interpretations of the above ways of representing time series, consider the familiar AD/AS graph in Figure 1. The first thing to note is that what is observed are equilibrium relationships between Y and P (i.e., not a separate "Y-equation" or "P-equation"), and that their "overall" correlation determine the estimated coefficient in the reduced form VAR. In order to separately identify a supply and demand curve, we have to impose restrictions that allow us to recover the underlying structural parameters (in the SVAR). These restrictions are typically of the form that certain variables enter one equation but not the other. This is the "traditional" simultaneous equations way of achieving identification, and along the lines of Sims (1980), where the system is made recursive. In this way, a separate supply and demand curve can be derived. Note that the correlation between Y and P is totally different in the case of a shift of the demand rather than supply curve, and with equal amounts of supply and demand shocks, the reduced form estimates would indicate that Y and P are "unrelated" due to the lack of structure.

Figure 1. AD/AS Diagram Determining the Price Level (P) and Output (Y)



When a distinction is made between the short and long run (or transition dynamics and steady state/long run equilibrium) which is done in the textbook AD/AS framework by introducing a long run supply curve (LAS) based on a natural rate of unemployment or potential output, this fits well into the common trends representation, where certain shocks have permanent effects while others have only temporary. Consider the case where the system is in long run equilibrium initially. If the long run supply curve shifts outward (a positive technology shock in the real business cycle terminology), output and the price level can both experience permanent changes, output going up and prices down. If there is a Keynesian style demand shock, on the other hand, the AD curve shifts out and AS is flat, output will increase over a certain period of time, but since the long run supply curve has not changed, output will eventually return to the long run equilibrium. In this framework as well as more sophisticated dynamic models, it is natural to identify shocks as having permanent or transitory effects and in terms of what variables will respond in the long and short run to a certain shock. A nominal shock is generally identified from a real shock by imposing the restriction that in the long run, only the price level is affected by the nominal shock. There are however no restrictions on the transitions dynamics, and there is therefore room for temporary effects on output from the nominal shock, where the duration of these temporary effects are determined empirically.

III. Theory

This section will provide a brief review of different theories relating to the determinants of the price level as well as the exchange rate with the focus on three things: what variables to include in the empirical study, long run equilibrium relationships (that can motivate cointegration) and theoretical implications that can be used to identify the empirical model.

A. Inflation Theories

There are several theories dealing with the determinants of inflation, but one feature of inflation that most economists would agree on is that in the long run, inflation is a monetary phenomenon. However, the exact links and other determinants of inflation are not generally agreed on. Often the point of departure in inflation studies is a money demand function. The demand for money come from the roles money play in the economy; as a medium of exchange, as a store of value and as a unit of account. Money as a medium of exchange and a store of value makes it desirable to hold. With increased economic activity the demand for money increase in most models as it does if the price level goes up, since agents demand real balances.

However, there is also a cost of holding money, which is the return that is foregone by not holding an asset that yields a return. In general, money is described as a dominated assets, since there are other government issued assets, like short term T-bills, that share the same inflation risk as money but provide a positive (nominal) yield. The risk is not identical however if we consider the cases where the investment horizon is not certain. In these cases, the T-bills are subject to an interest rate risk if they are sold before the maturity date (or have to be rolled over), while money holdings are not. In the cases of T-bill markets that lack liquidity and are subject to large variation in interest rates, there is no obvious way of measuring the alternative cost of holding money, since then the risk of other assets can become an issue. The observation about the investment horizon is sometimes labeled the speculative demand for money, since holding money provides the opportunity to purchase bonds when the price is low/interest rate is high. That is, if an investor wants to bet on falling bond prices, holding the wealth in the form of money provides the opportunity of making a good deal in the bond market. However, for a given investment horizon, this requires that the investor prefers the gamble to a certain return.

To summarize a vast literature, most (monetary) inflation theories would suggest that measures of the following concepts need to be included in an empirical study: the money stock, the price level, economic activity, and the alternative cost of holding money. Furthermore, when these variables have been accounted for, there should exist a stable money demand function, at least in the long run.[3] There are then the issues relating to the effects different monetary policies have on output and inflation where the views are less coherent. The most generally accepted conclusions however are that money is neutral in the long run and that anticipated changes in money/inflation are relatively poor instruments for affecting output. Unanticipated changes may however have short run effects on output in several types of models, although the magnitudes and duration is often a matter of controversies. In the empirical study, the less controversial long run neutrality will be exploited in the identification process, while the short run effects of nominal shocks will be left as an empirical matter to be investigated.

B. Exchange Rate Theories

There are few well accepted theories of movements in the exchange rate, especially when short run movements are considered. In the short run, issues like speculation, herd behavior and multiple equilibria are used as explanations of the difficulties in predicting short run comovements with "fundamental" variables. A slightly more convincing model of long run movements is provided by purchasing power parity (PPP)

$$e_t = p_t - p_t^* \,, \tag{6}$$

where e_t is the log of the nominal exchange rate and p_t and p_t^* the log of the domestic and foreign price levels, respectively. Empirical studies of PPP using the larger currencies (US$/Yen/DM) often reject PPP, while studies on smaller currencies yields more support for PPP, see, for example, Rogoff (1997) and Alexius (1997) for surveys.

In the standard monetary analysis of exchange rates (see,e.g., Obstfeld and Rogoff, 1996), it is the exchange rate that adjusts to restore or maintain the equilibria, with causality running from money to the price level and then to the exchange rate. In more trade related models, the exchange rate will in turn affect output through changes in competitiveness and thus imports and exports. A depreciation will for example be accompanied by an improvement in

[3]The concept of a money demand relationship is not arrived at without assumptions regarding the exogenous status of the other variables in the money demand equation and in the empirical part of the paper, it turns out that the other variables are not weakly exogenous. Citation marks are thus added to indicate that "money demand" or "income elasticity" is an equations/parameter that on the surface looks as these concepts in the theoretical models, but lack the structural interpretation.

the current account at some horizon. In the earlier models, this was the case already in the short run, but the literature then focused on the J-curve phenomenon, where a depreciation initially lead to a worsening in the current account before the improvement is realized (see, e.g. Dornbusch 1975, Isaac 1995). The explanation of the J-curve varies, but one general idea is that it takes time for quantities to adjust, so that there is no change in the exported and imported quantities initially, which leads to a deteriorating current account when a currency depreciates.[4] After this initial period, quantities adjust to the new prices so that the initial worsening of the current account is turned around to an improvement due to the depreciated exchange rate.

In the empirical model, the exchange rate and foreign price level will be included to study if PPP seem to be a reasonable long run equilibrium relationship that can be used to guide future policy decisions. Furthermore, the J-curve phenomenon will be used to identify the transitory shocks in the model by imposing the restriction that output will not respond contemporaneously with a foreign exchange shock.

IV. The Empirical Study

The theoretical discussion above suggests that (at least) six variables should be included in the empirical model measuring: money, the price level, economic activity, the exchange rate, the foreign price level, and the alternative cost of holding money. The data used in the study corresponding to the theoretical concepts discussed above is the end of period stock of broad money in billions of rials (M)[5], the Iranian consumer price index at the end of the year (P)[6], GDP at current market prices in billions of rials deflated by the Iranian CPI (Y)[7], the

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[4]The conditions for the effects on the trade balance of changes in the exchange rate will depend on the price elasticities of the trade balance, and it is relatively straight forward to imagine that these elasticities will be dependent on the time horizon considered.

[5]A number of measures could be used for the money stock, and here broad money is used since it is the only series that can be found for the entire sample period. If data can be found for other monetary aggregates, it could be interesting to see if the main conclusions are valid also for these aggregates.

[6]Since the focus in money demand models is on consumer behavior, it is natural to use CPI as the measure of the domestic price level, although there obviously are several alternative measures of the price level, e.g., the GDP deflator.

[7]Both the amount of transactions and the level of real income can be approximated by real GDP, where nominal GDP has been converted to real GDP by using the CPI rather than the GDP deflator, since the price measure used should be consistent with the calculation of real GDP.

free/black market exchange rate in rials per US dollars (E)[8], and the US consumer price index at the end of period (P*)[9].

The model does not include a measure of the alternative cost of holding money, for example, the return on short-term government debt (which is closest to money with respect to both default risk and inflation risk). To be a useful measure, the instrument should be traded on a well functioning capital market, and in the case of Iran, there are no short-term government bonds traded in such a market. An alternative measure for the cost of holding money would be the inflation rate if the real interest rate is assumed to be fairly constant and if the expected inflation can be approximated by the (past) inflation rate. Including inflation in the money demand function does however only make sense under certain assumptions about the order of integration in the data. This will be discussed further in connection with stationarity of the data.

In addition to the theoretical discussion, some variables have been added in order to achieve a well-specified model. First, Iran's position as one of the world's largest oil producers motivates including the real oil price as an exogenous stochastic variable.[10] Furthermore, during the period, Iran has undergone some indisputable events motivating the introduction of two zero/one dummy variables, one that accounts for the revolution, taking the value zero before 1979 and one after that, and a second dummy for the war with Iraq, which takes the value one during 1979 to 1989 and zero otherwise. The dummies are included as a mean of capturing the structural changes that can be observed in the data which would lead to estimation problems if ignored.

Including deterministic zero/one dummies in the system without restricting them to the cointegrating vector implies that average growth rates can change at the time of the structural change as well as the equilibrium levels of the cointegrating relationships, while the cointegrating vectors remains unchanged. In terms of, for example, PPP this implies that the cointegrating vector is unchanged but that the implied real exchange rate is allowed to change. Conditional on changes in the real oil price and the dummies, the model behaves like a model without exogenous variables.

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[8]The nominal exchange rate is slightly difficult in Iran, due to the multiple exchange rates and a number of restrictions in the exchange market. However, the black/free market rate adjusts continuously over time, which makes it a candidate for the nominal exchange rate.

[9]Foreign prices can be measured in a number of ways. Given that the exchange rate is in dollars, the price level has to be measured in dollars, but the question of what countries to include still remains. There are at least two candidates that appear reasonable, the US price level, or a trade-weighted average of the world price level expressed in dollars. However, the latter measure involves unilateral exchange rate movements in other currencies vis a vis the dollar, and that can show up quite strongly in the measure of the foreign price level. In the case PPP was valid on a global scale with rapid adjustment, this would not be a problem, however, if this is not a valid assumption the US price level is likely to be a better measure.

[10]Measured by the international oil price in US dollars deflated by the US CPI, more specifically Dubai, Fateh 32 API, fob Dubai which is the only price available for the entire period in the IMF database.

Annual data covering the period 1959 to 1996 has been used.[11] The main motivation for using annual data is that in studies of long run equilibrium relationships it is useful to have data covering as long a period as possible, since the adjustment to equilibrium can be slow (see, e.g., Rogoff 1997 for a discussion of the observed half life of deviations from PPP). That is, if adjustments were slow, 50 annual observations would tell us more about cointegrating relationships than 100 monthly observations. The draw back of using annual data is however not only that there are fewer observations, but also that structural breaks become a more pertinent issue and has to be addressed, which this study clearly illustrates.

The levels and first differences of the series are displayed in Figure 2, where the presence of a trend in the level data is evident, while the data in first differences look reasonably stationary, which leads to the more formal investigation of stationarity and cointegration.

A. Stationarity and Cointegration

The issues of stationarity and cointegration is investigated in the Johansen framework described above, which utilizes the VEC representation of the system of endogenous variables. The vector of endogenous variables that will be employed in the remainder of the paper is $x = [y \quad m \quad p \quad e + p^*]$, where the lower case letters indicate that the variables discussed earlier are in logs. Note that the exchange rate and the foreign price level have been combined into one variable in the system, which has been done to save some degrees of freedom in the estimation. Naturally, this implies that the coefficients on these variables have been restricted to be the same in all cases where the variables enter, that is, both in the short run dynamics and in the cointegrating vectors. The latter part is fully consistent with our theoretical considerations, since both coefficients are zero and one in the money demand and PPP vectors, respectively. The restrictions on the short run does not have the same theoretical underpinning, but is motivated by the short time series, and that it does not seem particularly unreasonable.

The results of the cointegration tests are displayed in Table 1. Since the results can be sensitive to both the lag length and the assumption regarding the deterministic components, the table include the results for 1-3 lags and different assumptions regarding the deterministic trend. There seem to be clear evidence of two cointegrating vectors, which is what our previous theoretical discussion suggests.[12]

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[11]The end of period refers to the Iranian year, which ends in March, e.g., what is labeled here as 1996 covers March 21 1996 to March 20 1997 and corresponds to the Iranian year 1375.

[12]There are however some caveats with respect to the critical values used here. First, the asymptotic distribution will in general change with the inclusion of exogenous variables, and secondly, the asymptotic distributions are not always the best thing to use in small sample. Given the relatively clear cut results that the asymptotic critical values render, and the fact that a fair amount of judgment always has to go into the study of cointegration and that the results are in correspondence with the theory, it does not at this point seem too necessary to simulate the appropriate empirical distributions.

Figure 2. Data in Levels and First Differences

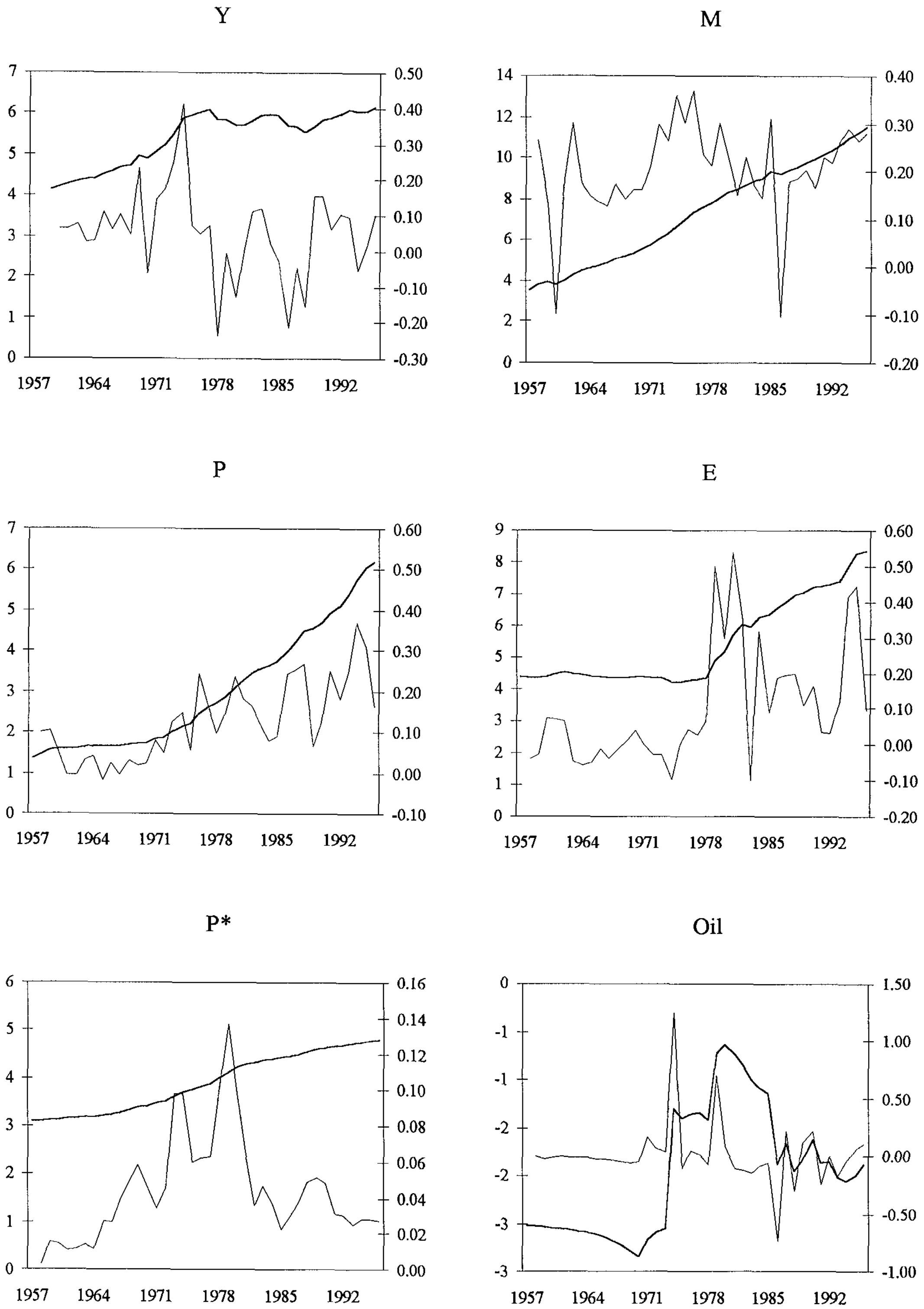


Table 1. Cointegration Tests

	LRmax					LRtr				
	Lags			Critical value		Lags			Critical value	
H_0	1	2	3	0.90	0.95	1	2	3	0.90	0.95
Constant in cointegrating vector, linear trend in data										
$r = 0$	**36.04**	**37.65**	**36.19**	24.73	27.07	**64.51**	**65.67**	**69.29**	43.95	47.21
$r \leq 1$	**23.02**	<u>19.25</u>	**21.43**	18.60	20.97	<u>28.47</u>	<u>28.02</u>	**33.10**	26.79	29.68
$r \leq 2$	4.97	8.19	7.13	12.07	14.07	5.45	8.77	11.67	13.33	15.41
$r \leq 3$	0.49	0.58	4.54	2.69	3.76	0.49	0.58	4.54	2.69	3.76
Trend in cointegrating vector										
$r = 0$	**40.31**	**41.37**	**39.12**	29.12	31.46	**81.18**	**82.17**	**77.43**	59.14	62.99
$r \leq 1$	**29.71**	**26.45**	<u>21.45</u>	23.11	25.54	<u>40.87</u>	<u>40.80</u>	38.31	39.06	42.44
$r \leq 2$	8.07	9.43	10.89	16.85	18.96	11.15	14.35	16.86	22.76	25.32
$r \leq 3$	3.09	4.92	5.96	10.49	12.25	3.09	4.92	5.96	10.49	12.25
Constant in cointegrating vector, no linear trend in data										
$r = 0$	**68.83**	**42.73**	**39.74**	25.56	28.14	**119.6**	**94.97**	**99.09**	49.65	53.12
$r \leq 1$	**35.92**	**31.63**	**31.03**	19.77	22.00	**50.77**	**52.24**	**59.35**	32.00	34.91
$r \leq 2$	10.10	12.52	**21.34**	13.75	15.67	14.84	**20.61**	**28.32**	17.85	19.96
$r \leq 3$	4.75	<u>8.10</u>	6.98	7.52	9.24	4.75	<u>8.10</u>	6.98	7.52	9.24

Note: Critical values from Osterwald-Lenum (1992). Bold (underlined) numbers indicate that they are significant at the 5 percent (10 percent) level.

I(1) or I(2)?

Some variables may not be stationary until they have been differenced twice, indicating that they are I(2) rather than I(1). There may also exist cointegrating vectors at different levels of integration, transforming sets of I(2) variables to I(1) or even I(0), in addition to the more traditional case where only linear combinations from I(1) to I(0) are considered. Johansen (1992) illustrates this with UK data including money and prices. In the present study, the same variables for Iran are studied, and visual inspection suggest that the price level may be I(2), since it is not obvious that the first difference of the series is stationary. At this stage it is appropriate to note that the order of integration of the price level determines the order of integration of the inflation rate measured as the first difference of the (log of) the price level. This implies that if the price level is I(1), the inflation rate is I(0) by definition, which in turn implies that the inflation rate cannot enter a cointegrating relationship with among other variables, the price level. In other words, if there is a cointegrating vector from I(1) to I(0), inflation cannot be one of the arguments in such vector. If, on the other hand, (at least) the price level is I(2), and thus inflation is I(1), there can be instances where both variables can be present in one cointegrating vector. One example is when money is also I(2), while real money, that is, the difference between money and the price level is I(1), in which case the inflation rate may cointegrate with real money.

Johansen has suggested that the presence of I(2) components can be tested in analogy with the test of I(1) components, by using reduced rank regressions. The test is a two step procedure, where the number of I(0) components are first determined with the standard cointegration trace test, and given the number of I(0) components, the trace test is used to determine the number of I(2) components, which is naturally the number of variables minus the number of I(0) and I(1) components.

However, in the case there is no a priori view on the number of I(2) components, a more appropriate way of conducting the test is to perform a joint test of the number of I(1) and I(2) components. This strategy ensures that the test has the appropriate size asymptotically, which is only the case for the two step procedure if the number of I(2) components is zero according to Jørgensen et al (1996). The authors suggest that the two step procedure can be used as a misspecification test in a standard I(1) analysis, which (at least implicitly) has as the null that no I(2) components are present. The results of the two step test ($Q_{r,s}$) and joint test ($S_{r,s}$) for the present study are displayed in Table 2.

Table 2. Test for Order of Integration

r	$Q_{r,s}$				$S_{r,s}$			
0	110.68	64.78	29.76	10.71	**176.35**	**130.45**	**95.43**	**76.38**
	s = 0	s = 1	s = 2	s = 3	s = 0	s = 1	s = 2	s = 3
1		88.17	42.76	9.19		**116.19**	**70.78**	37.20
		s = 0	s = 1	s = 2		s = 0	s = 1	s = 2
2			**50.72**	**12.30**			59.48	21.07
			s = 0	s = 1			s = 0	s = 1
3				28.46				29.04
				s = 0				s = 0
n-r-s	4	3	2	1	4	3	2	1

Note: *n-r-s* is the number of I(2) components, and bold number indicate that the observed value leads to a rejection at the five percent level of the null that consist of the *r* and *s* combination in a certain cell.

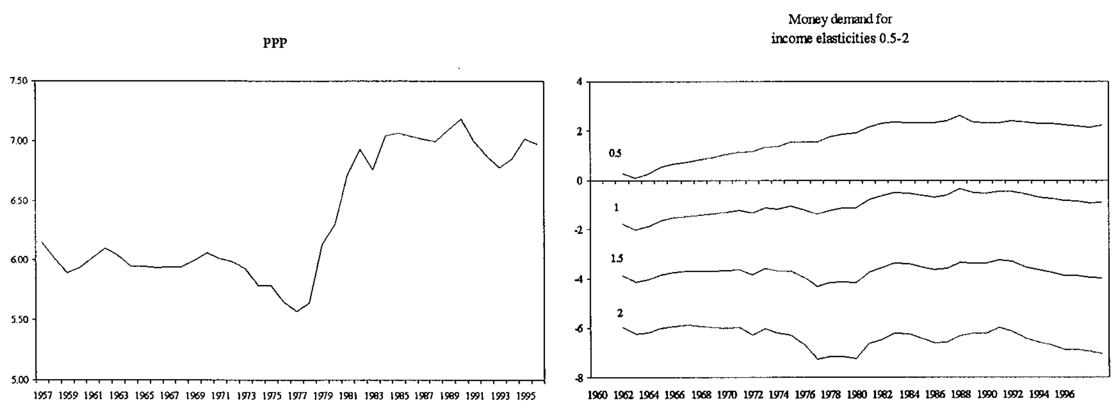
The table indicates that the two step test arrives at $r = 2$ and $s = 2$, so that the number of I(2) components is zero ($n - r - s = 0$), that is, the estimated model passed the I(2) misspecification test according to the above discussion. In the following estimation, the assumption of zero I(2) components will be maintained.[13]

[13]However, the reader who disagrees with the null of zero I(2) components can employ the, in that case, more appropriate joint test. In that event, there are indications of a potential I(2) component, which will be ignored in the following presentation. In that case, a reformulated model including real money, real output, the inflation rate and PPP can be used to remove the potential I(2) component. However, such model suffers from other specification problems and has therefore not been developed further.

B. Testing Theoretical Cointegrating Vectors

The two cointegrating vectors that have been estimated will be subject to formal test shortly, but it is useful as a first check to plot the cointegrating vectors suggested by theory. With the variable vector $x = [y \quad m \quad p \quad e + p^*]$, theory suggests that there is one cointegrating vector related to PPP and one to "money demand," and these are displayed in Figure 3. (Note that here money demand is replaced by "money demand," since the empirical study does not indicate that the other variables are weakly exogenous, see fotnote 3).

Figure 3. The Theoretical Cointegrating Vectors



The PPP vector is given from theory in its entirety as $e + p^* - p$, that is, the cointegrating vector associated with the variable vector x is $\beta_{PPP} = [0 \quad 0 \quad -1 \quad 1]$. The "money demand" function is not completely given from theory, since the "income elasticity" is only given if the quantity theory is applied. The "money demand" function is therefore plotted for "income elasticities" ranging from 0.5 to 2, that is, $\beta_{MD} = [\eta \quad 1 \quad -1 \quad 0]$, with $\eta = 0.5, 1, 1.5, 2$. The PPP relationship seems to be relatively stationary, with a clear level shift at the time of the envisaged structural break. The "money demand" function does not look well behaved for values under 1.5, but looks stationary for values between 1.5 and 2.

The next step is to investigate formally if the theoretical cointegrating vectors are in the cointegrating space. This is done by a LR test, which follows a χ^2 distribution with degrees of freedom equal to the number of restrictions. Since also these results can be sensitive to the chosen lag length, the test results are again displayed for 1-3 lags in Table 3.

The first hypothesis is that theoretical cointegrating vector suggested by PPP is consistent with the estimated cointegrating vectors. In none of the cases can the hypothesis be rejected at the 5 percent level, although in the case of two lags, the hypothesis would be marginally rejected at the 10 percent level. The second hypothesis is regarding "money demand", with the "income elasticity" unrestricted and the estimate displayed in the table. This hypothesis cannot be rejected at any normal level, which is also the case when a joint test of the two previous hypotheses is conducted. In the final rows of the table, the corresponding cases where the "income elasticity" is restricted to 1, that is, in line with the quantity theory, is tested. This further restriction on the "money demand" function can be rejected in all cases.

Table 3. Tests of the Theoretical Cointegrating Vectors: PPP and "Money Demand"

	Lags					
	1		2		3	
H_0	LR (p-value)	$\hat{\eta}$	LR (p-value)	$\hat{\eta}$	LR (p-value)	$\hat{\eta}$
(1) $e+p^*-p \sim I(0)$	3.38 (0.18)	(-2.862)	4.93 (0.08)	(-1.720)	2.46 (0.29)	(-1.727)
(2) $m-p-\eta y \sim I(0)$	0.05 (0.82)	-2.554	0.38 (0.54)	-1.858	0.01 (0.93)	-1.708
(3) (1)∩(2)	3.47 (0.33)	-2.895	5.35 (0.15)	-1.834	2.46 (0.48)	-1.725
(4) $m-p-y \sim I(0)$	14.95 (0.00)	Restricted 1	14.46 (0.00)	Restricted 1	14.72 (0.00)	Restricted 1
(5) (1)∩(4)	17.72 (0.00)	Restricted 1	18.56 (0.00)	Restricted 1	15.66 (0.00)	Restricted 1

To summarize the results so far, we have found that the system has two cointegrating vectors that are consistent with the theoretical vectors suggested by PPP and a "money demand" function, and that the "income elasticity" is around 1.5 to 2. In the common trends model below, the estimated model with two lags will be used, together with the estimated "income elasticity" of about 1.8.

C. The Common Trends Model

The focus so far has been on the cointegrating properties of the time series, which did not required that any structure was imposed to identify the model. In the next step, however, identification is an important ingredient in the modeling process. The above tests suggest that the system of four variables has two cointegrating vectors, and thus in the common trends terminology is driven by two common stochastic trends ($n-r=2$). Expressed differently, of the four different shock to the system, two will affect only the short run, while the two other can have both short and long run effects, since they are driving the two stochastic trends. The next step is to consider what these shocks represent and how they can be identified.

Identification

Given the variables included in the system, it is quite natural to consider one real (or technology/supply side) shock and one nominal (or monetary) shock driving the long run or the common stochastic trends. In more concrete terms, the real shock can include technological innovations, tax reforms and changes in human capital from education or learning in more general terms. The nominal shock is more naturally linked to unanticipated changes in the money stock, which in turn could be due to factors such as interest rate changes, changes in reserve requirements or tax reforms affecting the attractiveness of holding money. In the case of Iran, money supply is more a function of quantitative controls, so (unanticipated) changes in the allocated amounts would be naturally considered as nominal shocks. To separately identify the real and nominal shocks, one restriction is needed on the long run impacts on the variables for the two shocks (i.e., one restriction is imposed on the A matrix in the CT representation). As discussed in the theory section, a common and relatively uncontroversial assumption is to restrict the long run response in output to the nominal shock to be zero, that is, that money is neutral in the long run (see, e.g., King et al, 1991, or Blanchard and Quah, 1989). It is important to realize that the restriction is only present in the long run, and it is still possible that the nominal shock has short run effects on output (through the $\Phi(L)$ polynomial). Furthermore, the definition of the short run here is in the sense of the estimated model, and the effects can be present for several years, which is more likely to be classified as medium run from a policy perspective.

In addition to the permanent shocks, the system has two transitory shocks that require one assumption to separately identify them. One shock can be viewed as an aggregate demand shock of the type encountered in basic AD/AS models or more sophisticated intertemporal models, and the other related to temporary shocks to the foreign exchange market (or speculation). Both aggregate demand and speculation would in most theoretical models have only temporary effects on the variables without affecting the long run equilibrium, which is consistent with their potential impact in the empirical model. The issue is to separately identify the two shocks, and one restriction on the contemporaneous responses to the shocks is needed (i.e., on R_0 in the VMA representation). Here the assumption is that the foreign exchange (FEX) shock does not affect real output within the same period, which is motivated by the J-curve phenomenon discussed in the theory section.

The Long Run

Focusing on the long run behavior of the endogenous variables, the estimated common trends model can be summarized as follows[14]

$$\begin{bmatrix} y \\ m \\ p \\ e+p^* \end{bmatrix} = X_0 + \begin{bmatrix} \underset{(0.009532)}{0.040944} & \underset{(-)}{0} \\ \underset{(0.019264)}{0.000613} & \underset{(0.013296)}{0.060075} \\ \underset{(0.028821)}{-0.074479} & \underset{(0.013296)}{0.060075} \\ \underset{(0.028821)}{-0.074479} & \underset{(0.013296)}{0.060075} \end{bmatrix} \tau_t + D(L)\varepsilon_t, \qquad (7)$$

where $\tau_t = \begin{bmatrix} \tau_t^{real} & \tau_t^{nom} \end{bmatrix}'$, which follow a random walk with drift described by

$$\tau_t = \begin{bmatrix} 1.871508 \\ 3.303170 \end{bmatrix} + \tau_{t-1} + \phi_t. \qquad (8)$$

The common trends representation generates coefficient estimates that are consistent with what we would expect from the theoretical discussion. For example, the long run effect of a positive real shock is that output increases in a statistical significant way. Since there is no significant long run response in money due to this shock, the price level declines and the currency appreciates. For the nominal shock we have that all the nominal variables increase significantly, while the zero response in output is an identifying assumption.[15] The deterministic part in the stochastic trends also suggest that the nominal trend has been relatively strong compared to the real trend.

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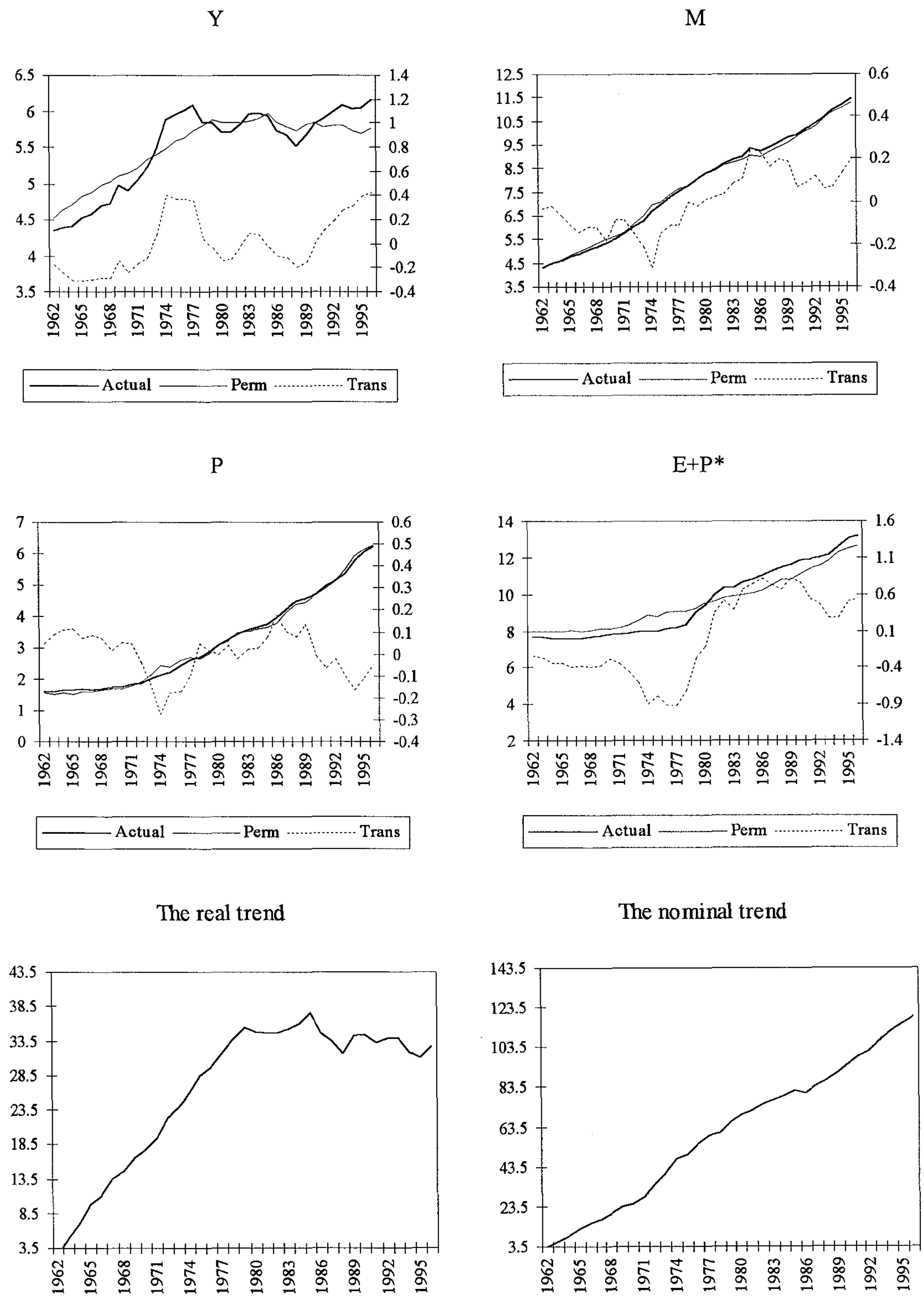
[14] Note that the zero in the top right hand corner of the A matrix does not come from the estimation but from the identification.

[15] Note that the coefficient are restricted by the cointegrating vectors as well as by the identifying assumption, so that in fact there is only four free parameters to estimate, which explains that some coefficients are the same.

Figure 4. The Permanent and Transitory Components



Transitory vs. Permanent Components

In many cases, especially in policy discussions, it is of interest to decompose the series into its transitory (or cyclical) and permanent (or structural) components. The empirical decomposition arrived at here is based on the number of cointegrating vectors and is displayed in Figure 4. The transitory components does not necessarily look stationary due to the fact that they are only stationary conditional on the exogenous variables. The permanent component can be decomposed further into the two stochastic trend components, that is, into the real and nominal trends, which are also displayed.

The permanent component in output is totally determined by the real trend by construction since that was the assumption used to identify the trends. The relatively volatile behavior of output is reflected in both the fact that the real trend is more volatile that the nominal trend, and in the relatively large transitory component in output. The permanent components in money and the price level, are on the other hand moving very much in line with the nominal trend as expected. From the beginning of the 1980's this seems to be the case also for the nominal exchange rate adjusted for the foreign price level. Note also that the transitory components for the nominal troika are displaying similar patterns, with apparent level shifts occurring after the revolution. This "non-transitory" behavior is then accounted for by the included dummy variables. In the same way, the large positive transitory components in output in the early seventies were concurrent with the substantial increases in real international oil prices (included as a stochastic exogenous variable).

The Dynamics

To study how the shocks are propagated through the system, the VMA representation is used to simulate impulse responses. The impulse responses with 95 percent confidence intervals are depicted in Figures 5–7 for the variables in the system. Furthermore, the shocks will generally create deviations from the long run equilibria implied by the cointegrating vectors representing "money demand" and PPP, and the adjustments back to the equilibria are also depicted in the figures.[16] This illustrates the fact that adjustments to equilibria depend on what shock created the deviation from the equilibria. In other words, the answer to the questions like what is the half-life of a PPP deviation is not independent of which shock created the deviation.

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[16]These graphs can basically be obtained by taking the appropriate linear combinations of the impulse responses of the original series, although to generate the confidence bounds the model is reestimated with the cointegrating vectors as two of the variables and appropriate adjustment of the cointegrating vectors.

Figure 5. Responses to the Real Shock

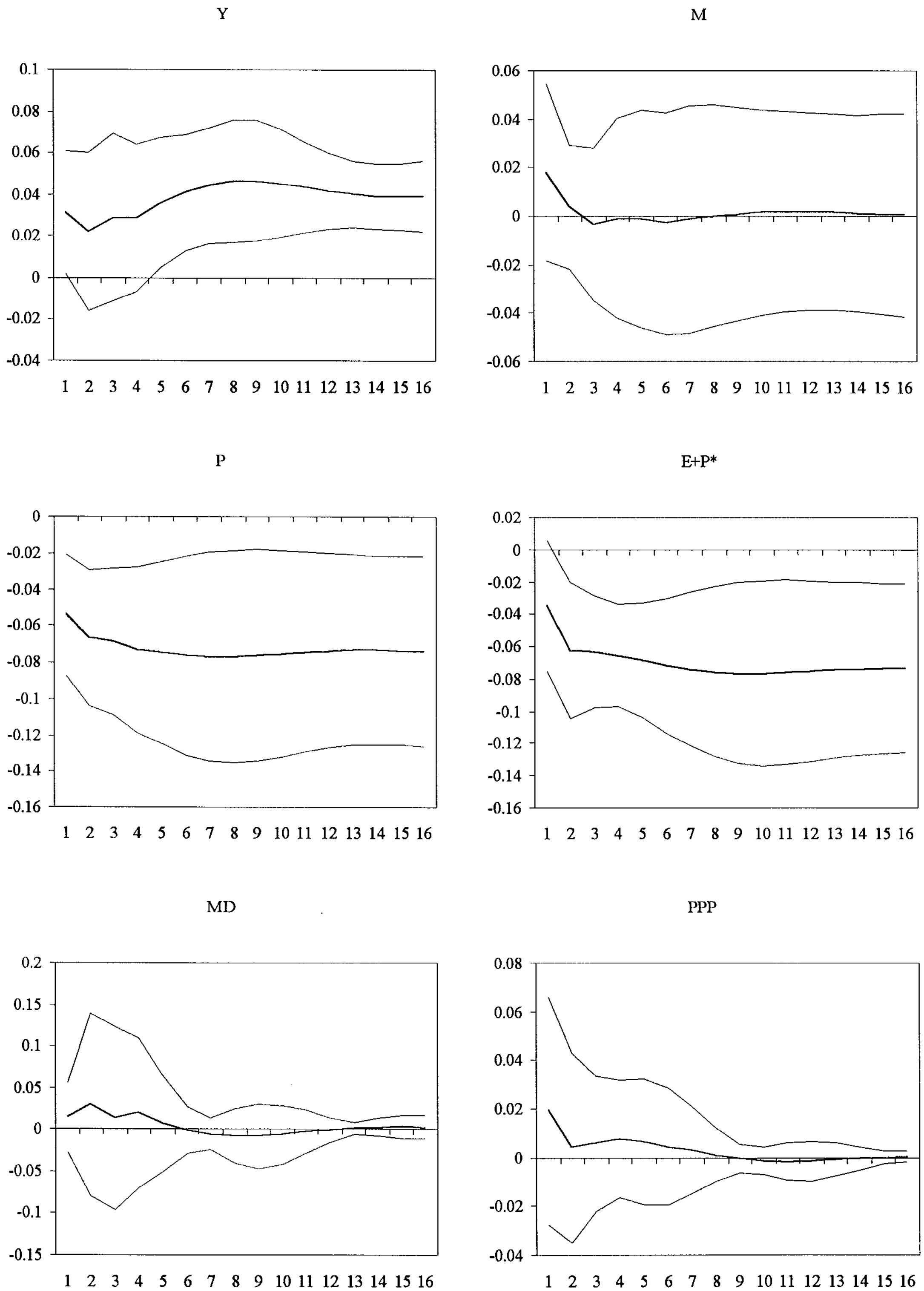
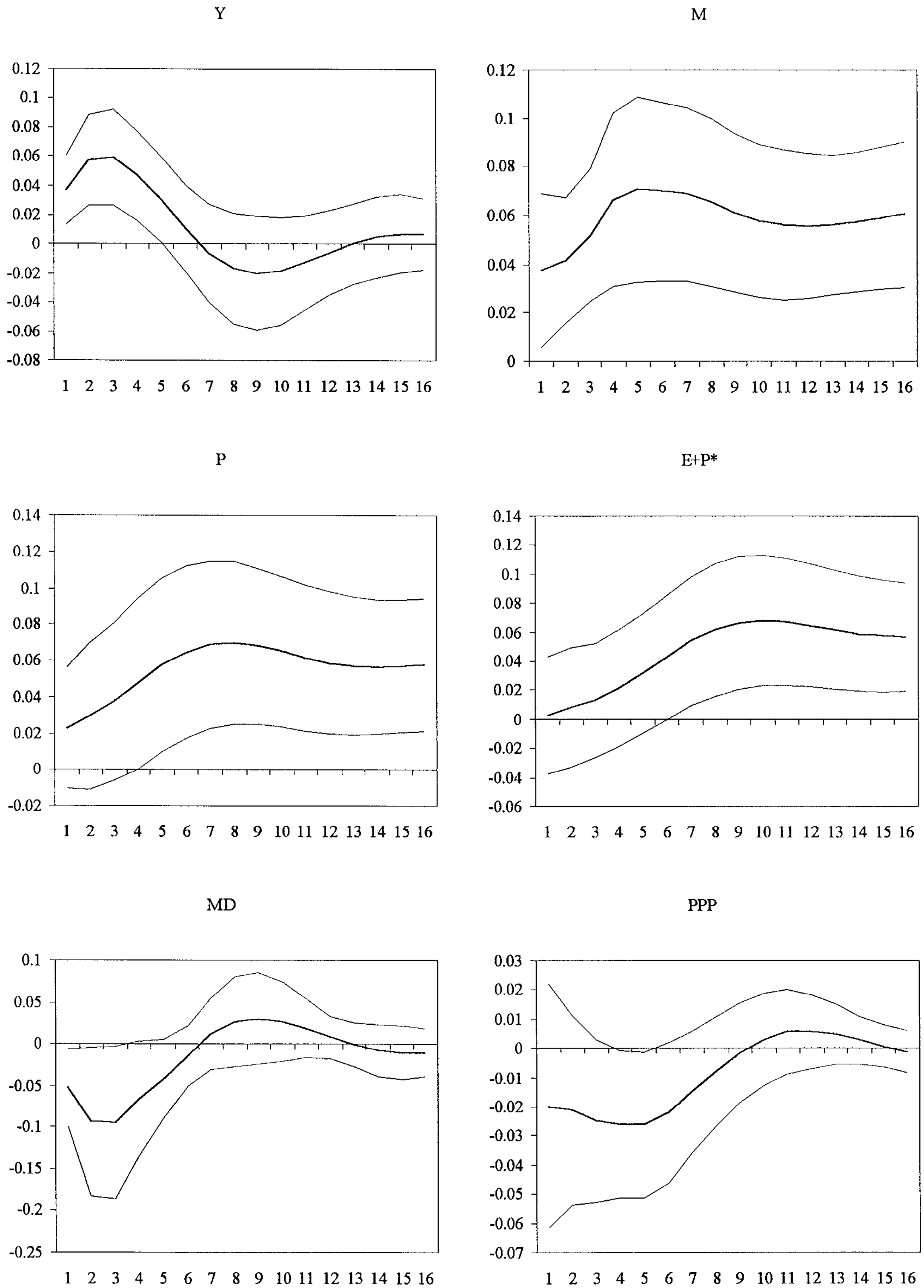


Figure 6. Responses to the Nominal Shock



The permanent real shock can affect all variables at all horizons, that is, there are no identifying restrictions imposed on the responses to this shock. First, there is a significant response in output at all forecast horizons, which is very much in line with what is expected from a real/technology shock. Secondly, the reduction in the price level and exchange rate at all horizons is also statistically significant and in line with the theoretical models, given that broad money does not display any significant response. The real shock does not give rise to any significant deviation from the long run money market equilibrium, since the lower price level offsets the increase in income. The nominal exchange rate depreciates with a slight lag compared to the change in price level, and the associated real appreciations (i.e., deviations from PPP) are not statistically significant at any horizon.

To separately identify the nominal shock from the real, the restriction that output cannot respond to the nominal shock in the long run was imposed. This does not, however, restrict the short run response of output, which is evident in the graph. Output increases in response to the nominal shock, and the effect is statistically significant for about 4 years. That is,, from an empirical point of view, the "short run" is about 4 years, quite a long period from a policy perspective. As expected, the nominal shock also induces money growth and inflation, with a permanent increase in the price level as a result. The price level seems to be increasing, that is, there is inflation, for as many periods as there is a significant effect on output. The nominal shock is also accompanied by a depreciation of the nominal exchange rate that is statistically significant in the long run. However, the depreciation lags the increase in the price level, creating an appreciation in the real exchange rate that is borderline significant in the medium term. After about 7-8 years, there are no significant deviations from PPP remaining. The adjustment in the money market seems to be a little faster, with no significant deviation left after about 3-4 years, but with larger initial deviations.

The temporary foreign exchange shock was identified by imposing the restriction that output cannot respond within the first period. The most prominent response is in the nominal exchange rate, which supports the labeling of the shock. Since the domestic prices do not change, there is a significant real depreciation (i.e., deviation from PPP) for 3-4 years. There is also a temporary increase in output that is statistically significant in year 3 and 4, which again is what is expected from theory. In the money market, the tightening following increased output is somewhat relived by a slight and temporary increase in the stock of broad money.

Figure 7. Responses to the FEX Shock

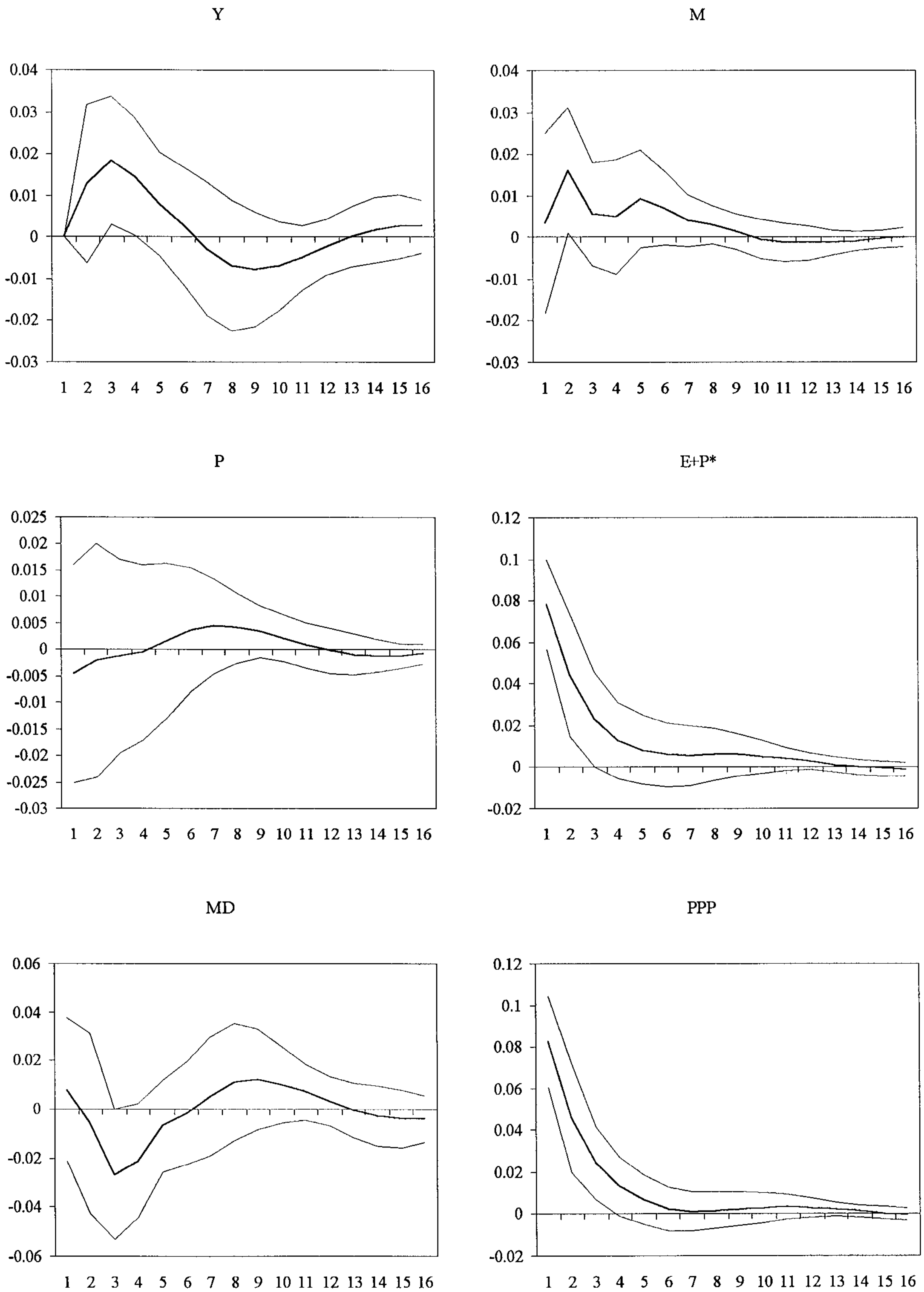
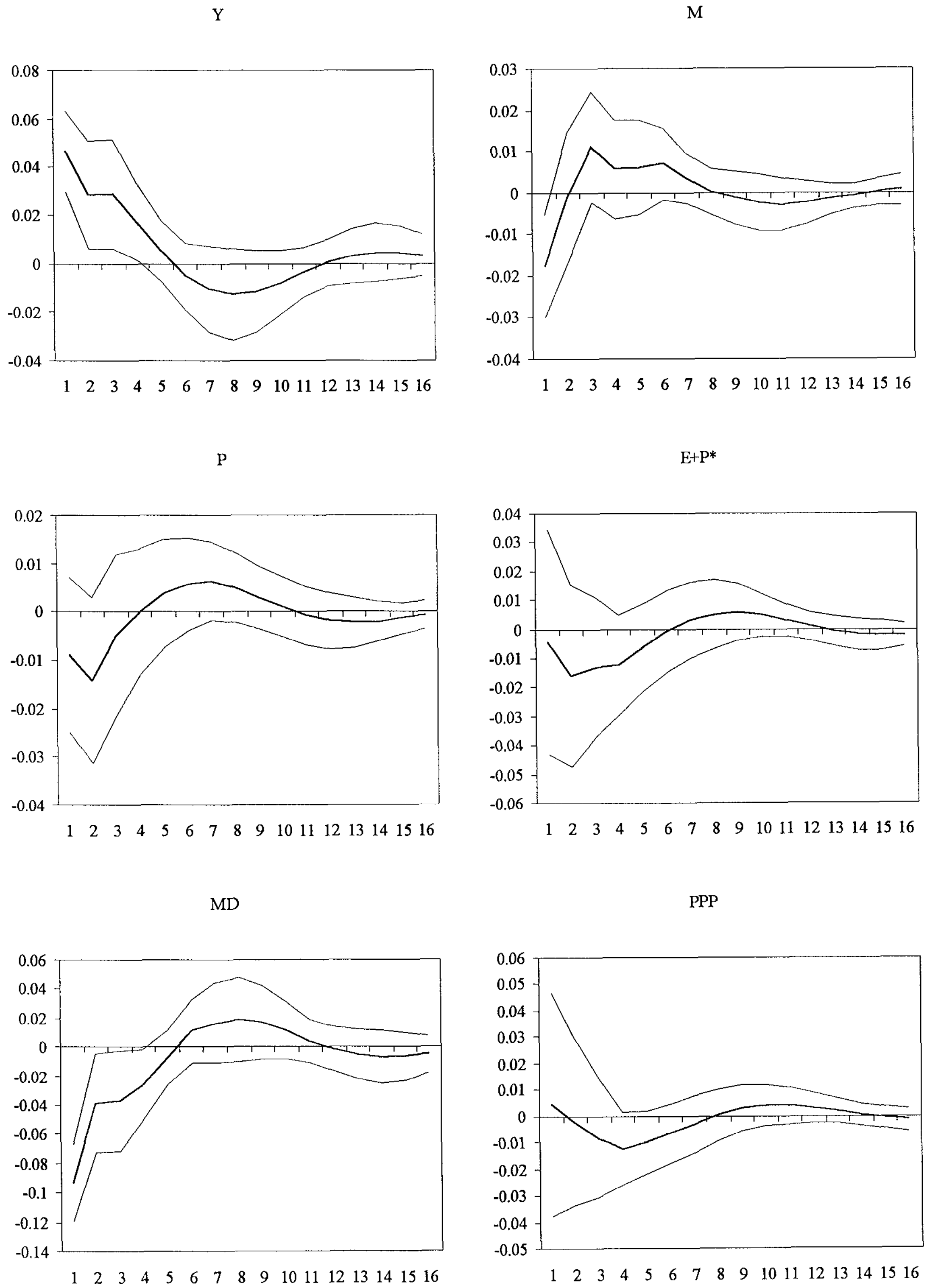


Figure 8. Responses to the Aggregate Demand Shock



The demand shock does not require further identifying assumptions beyond its temporary nature. Again, the responses are in line with theoretical models; output increases significantly over a 4-year period, while the price level is more or less unchanged. In the short run, there is also a monetary response that is significant, suggesting a countercyclical monetary policy, contributing to the tightening in the money market (as compared to its long run equilibrium) concurrently with the increase in output. With little action in the price level or exchange rate, it is not surprising that the shock does not create any significant deviation from PPP.

Variance Decomposition

The variance decompositions analyze how much of the forecast errors in the variables come from the different shocks. This will depend on the forecast horizon, thus the variance decompositions are depicted for different forecast horizons in Figure 9. It should be noted that this exercise is aimed at understanding the source of the non-forecastable movements in the variables, that is, the deterministic part is disregarded.[17]

One question that has received some attention in the literature is whether permanent technology shocks are important not only for the long run, but also for understanding business cycle fluctuations (see e.g. Blanchard and Quah 1989 and King et al 1991). The graph indicate that fluctuations at business cycle frequencies in output are dominated by other factors than the technology shock, with demand shocks dominating in the short run and then the nominal shock gaining importance. By construction, the real shock will totally determine the stochastic part of output in the long run, but still after 15 years, it contributes just a little more than 50 percent to the forecast error variance. Another striking feature is that the variance decomposition of the price level indicates that the real shock plays an important role in explaining its stochastic component, although the nominal shock becomes more important over time. The forecast error in money, on the other hand, is totally dominated by the nominal shock, while the foreign exchange shock has a very prominent role in accounting for the forecast error in the nominal exchange rate.

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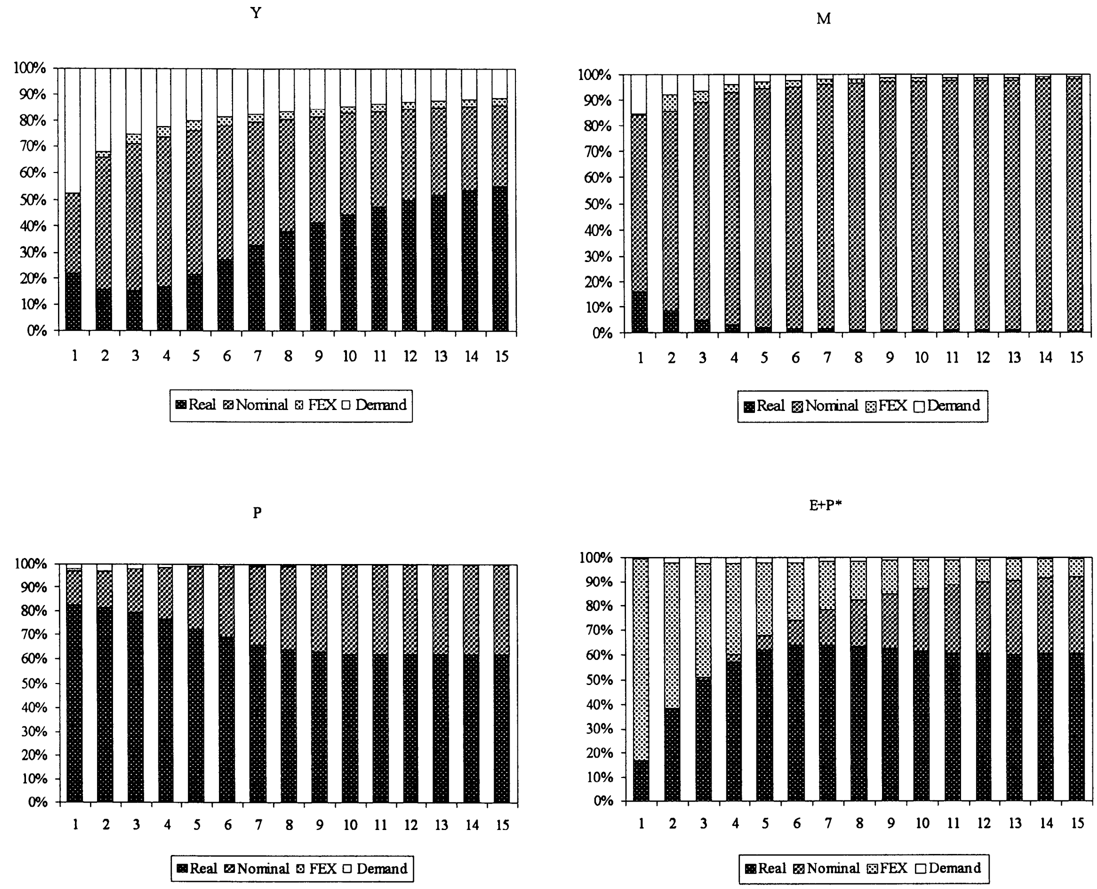
[17]For example, the stochastic trends contain both a deterministic drift and a permanent shock, and here the focus is on the unexplained variation, i.e., the shock. Since the underlying model includes exogenous stochastic variables, the variance decomposition is done conditional on the movements in these variables.

Figure 9. The Variance Decomposition



V. Concluding Remarks

To summarize the main findings, the study found two cointegrating vectors consistent with PPP and a stable "money demand" function, although there have been structural changes associated with the revolution and the Iran-Iraq war. From a policy perspective, this suggests that the free/black market rate behaves according to our existing exchange rate theories in the long run, and could potentially provide guidance to what a reasonable level is for a unified rate (after possible transitory elements influencing the black market rate are considered and adjusted for).

The study also found evidence of positive effects on output in the short to medium term from unanticipated monetary expansions, however, since the price level can be expected to increase permanently and the exchange rate depreciate in response to the nominal shock, this type of policy is not consistent with the goals of low and stable inflation and a stable unified exchange rate. Instead the model gives support for more supply side oriented policies that could create both output growth and low inflation (or even deflation if not accompanied by monetary expansions). These policies could comprise tax reforms, liberalized labor markets and further strengthening of the human capital in the economy.

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